SUSTAINABLE DIETS AND BIODIVERSITY

DIRECTIONS AND SOLUTIONS FOR POLICY, RESEARCH AND ACTION

FAO

Bioversity International

SUSTAINABLE DIETS AND BIODIVERSITY

DIRECTIONS AND SOLUTIONS FOR POLICY, RESEARCH AND ACTION

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PREFACE

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The book presents the current state of thought on the common path of sustainable diets and biodiversity. The articles contained herein were presented at the International Scientific Symposium "Biodiversity and Sustainable Diets: United Against Hunger" organized jointly by FAO and Bioversity International, held at FAO, in Rome, from 3 to 5 November 2010. The Symposium was part of the official World Food Day/Week programme, and included one of the many activities in celebration of International Year of Biodiversity, 2010. The Symposium addressed the linkages among agriculture, biodiversity, nutrition, food production, food consumption and the environment.

The Symposium served as a platform for reaching a consensus definition of "sustainable diets" and to further develop this concept with food and nutrition security, and the realization of the Millennium Development Goals, as objectives.

In the early 1980s, the notion of "sustainable diets" was proposes, with dietary recommendations which would result in healthier environments as well as healthier consumers. But with the over-riding goal of feeding a hungry world, little attention was paid to the sustainability of agro–ecological zones, the sustainable diets' concept was neglected for many years.

Regardless of the many successes of agriculture during the last three decades, it is clear that food systems, and diets, are not sustainable. FAO data show that one billion people suffer from hunger, while even more people are overweight or obese. In both groups, there is a high prevalence of micronutrient malnutrition. In spite of many efforts, the nutrition problems of the world are escalating. Improving nutrition through better balanced nutritious diets can also reduce the ecological impact of dietary choices. Therefore, a shift to more sustainable diets would trigger upstream effects on the food production (e.g. diversification), processing chain and food consumption.

With growing academic recognition of environmental degradation and loss of biodiversity, as well as a dramatically increasing body of evidence of the unsustainable nature of agriculture as it is currently practiced in many parts of the world, renewed attention has been directed to sustainability in all its forms, including diets. Therefore, the international community acknowledged that a definition, and a set of guiding principles for sustainable diets, was urgently needed to address food and nutrition security as well as sustainability along the whole food chain

A working group was convened as part of the Symposium and a definition was debated, built upon previous efforts of governments (e.g., the Sustainability Commission of the UK), UN agencies (FAO/Bioversity Technical Workshop and Biodiversity and Sustainable Diets), and others. The definition was presented in a plenary session of the Symposium and accepted by the participants, as follows: *Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources*.

The agreed definition acknowledged the interdependencies of food production and consumption with food requirements and nutrient recommendations, and at the same time, reaffirmed the notion that the health of humans cannot be isolated from the health of ecosystems.

To address also the food and nutrition needs of a richer and more urbanized growing world population, while preserving natural and productive resources, food systems have to undergo radical transformations towards more efficiency in the use of resources, and more efficiency and equity in the consumption of food and towards sustainable diets. Sustainable diets can address the consumption of foods with lower water and carbon footprints, promote the use of food biodiversity, including traditional and local foods, with their many nutritionally rich species and varieties. The sustainable diets' approach will contribute in the capturing efficiencies through the ecosystem approach throughout the food chain. Sustainable diets can also contribute to the transition to nutrition-sensitive and climate-smart agriculture and nutrition-driven food systems.

A close involvement of civil society and the private sector is needed to engage directly all stakeholders in the fields of agriculture, nutrition, health, environment, education, culture and trade, along with consumers.

The Symposium served to position sustainable diets, nutrition and biodiversity as central to sustainable development. The Proceedings of the Symposium, presented in this publication, provide examples of sustainable diets, which minimize environmental degradation and biodiversity loss. Various case studies and practices are also presented bringing biodiversity to the plate, with data showing improvements in nutrient intakes through food biodiversity, as a counterbalance to the trend of diets low in diversity but high in energy which contribute to the escalating problems of obesity and chronic diseases. The Mediterranean Diet was showcased as a useful model.

The contents of this book provide an array of new directions and solutions for policy, research and action on sustainable diets, and useful contributions to the follow-up for the Rio+20 United Nations Conference on Sustainable Development, and its outcome document, *The Future We Want*.

Although the evidence base must be improved, existing knowledge warrants immediate action to promote sustainable diets and food biodiversity in nutrition-driven agriculture policies and programmes, as contributions to the achievement of food and nutrition security, the Millennium Development Goals, and post-2015 development agenda.

The contributions of all session chairpersons, rapporteurs, speakers and everyone who participated in the discussions and working groups were a vital part of the Symposium's successful outcomes. This book represents a significant international achievement.

Acknowledgements

The Symposium was organized by FAO and Bioversity International. The organizers are grateful for the collaboration of the CBD Secretariat, Ministry of Agriculture and Food and Forestry Policies of Italy, INRAN, CIHEAM-Bari, INFOODS, Alliance Against Hunger and Malnutrition, IUNS, and FENS. The Barilla Center for Food & Nutrition, IDRC and CTA are acknowledged for their contribution to this gathering of experts from many parts of the world to discuss with us these challenging emerging issues.

Overall leadership was provided by Barbara Burlingame, Principal Officer of the Nutrition and Consumer Protection Division of FAO. The technical and organizational support from Sandro Dernini, in collaboration with Ruth Charrondiere, Florence Egal, Stefano Mondovì and Barbara Stadlmayr and the very valuable administrative and logistical support from Giuseppina Di Felice and Nathalie Lambert, FAO staff, and Nadia Bergamini, Bioversity International staff, are acknowledged.

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Acronyms and abbreviations

AFROFOODS	INFOODS African Network of Food Data Systems
BCNF	Barilla Center for Food and Nutrition
BIOVERSITY	Bioversity International
CBD	Convention on Biological Diversity
CNR	National Research Council, Italy
CTA	Technical Centre for Agricultural and Rural Cooperation
CIBFN	Cross-cutting Initiative on Biodiversity for Food and Nutrition
CIISCAM	International Inter-university Centre for Mediterranean Food-Culture Studies, Italy
CIHEAM-Bari	International Centre for Advanced Mediterranean Agronomic Studies, Bari, Italy
CINE	Centre for Indigenous Peoples' Nutrition and Environment, Canada
CODEX	Codex Alimentarius Commission
ENEA	National Agency for New Technologies, Energy and Sustainable Economic Development, Italy
FAO	Food and Agriculture Organization of the United Nations
FENS	Federation of European Nutrition Societies
ICRAF	International Center for Research in Agroforestry, Kenya
IDRC	International Development Research Centre, Canada
INFOODS	International Network of Food Data Systems
INRA	National Institute for Agricultural Research
INRAN	National Research Institute for Food and Nutrition, Italy
IUNS	International Union of Nutritional Sciences
MDGs	Millennium Development Goals
MiPAAF	Ministry of Agriculture, Food and Forestry Policy, Italy
NGOs	Non-governmental organizations
RUTF	Ready-to-use therapeutic food

OPENING ADDRESSES

Changchui He
Deputy Director-General FAO, Rome
3 November 2010

As you are aware the theme for this year's World Food Day is "United Against Hunger". This theme underscores the fact that achieving food security is not the responsibility of one single party; it is the responsibility of all of us. The 2010 celebration also marks the 30th World Food Day, a celebration that has been observed around the world over the last three decades. The latest hunger figures show that 925 million people live in chronic hunger. While there is a welcome decline from the 2009 level, the number of hungry people remains unacceptably high. Furthermore, this number does not reflect all the dimensions of malnutrition. Micronutrient deficiencies, for instance, affect an estimated two billion people. Responding properly to the hunger and malnutrition problems requires urgent, resolute and concerted actions. It calls for united efforts by all relevant actors and at all levels.

Already, close to two million people around the globe have signed the "Against Hunger" petition, as part of an international advocacy and awareness campaign launched by FAO ("1BillionHungry.org"). It aims at placing pressure on political leaders and mobilizing all parties to take united action against hunger and malnutrition. As we are aiming to have as many signatures as possible by 29 November, when the petition will be presented to member countries on the occasion of the 140th session of the FAO Council, I am inviting all of you, if you have not yet done so, to sign the petition on the tables placed outside the room.

Coming back to this year's International Scientific Symposium, the theme for the symposium is "Biodiversity and Sustainable Diets: United Against Hunger", jointly organized by FAO and Bioversity International as a contribution to the 2010 International Year of Biodiversity.

For the first time, the concept of "biodiversity" is linked with the emerging issue of "sustainable diets" in exploring solutions for the problems of malnutrition in its various forms, while addressing the loss of biodiversity and the erosion of indigenous and traditional food cultures. Our purpose is to promote the development of new sustainable food production and consumption models.

There is currently no universally agreed definition of a "sustainable diet". However, a definition is needed to develop policy, research and programme activities for the promotion of sustainable food systems that minimize environmental degradation and biodiversity losses. There is growing academic recognition of the complexity of defining sustainability, as well as an increasing body of evidence showing the unsustainable nature of current food systems. A definition of sustainable diets shall therefore address sustainability of the whole food supply chain and thus provide guidance on promoting and applying the concept in different agro-ecological zones.

The alarming pace of food biodiversity loss and ecosystem degradation, and their impact on poverty and health makes a compelling case for re-examining food-agricultural systems and diets.

FAO has been working with member countries, international and regional partners for the past few years to determine the status and trends of plant genetic resources that feed the world. We looked into the key achievements as well as the major gaps and needs that require urgent attention. This effort has culminated in the publication of the Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture that was launched by the Director-General of FAO last week. The Report provides a wealth of information from over 100 countries for improving conservation and sustainable use of plant diversity to meet the key challenges of malnutrition, food insecurity and rapid climate change. It points out that plant diversity can be lost in a short lapse of time in the face of rapid climate change, population pressure and environmental degradation.

There is an urgent need to collect, document and better use this diversity including crop wild relatives, not least because they hold the genetic secrets that enable them to resist heat, drought, floods and pests. New and better-adapted crops derived from genetic diversity can offer more nutritious and healthier foods for rural and urban consumers, and provide opportunities to generate income and contribute to sustainable rural development. Now more than ever, there is a greater need to strengthen linkages among institutions dealing with plant diversity and food security, and with other stakeholders, at global, regional, national, and local levels. Far greater efforts are required to counteract the effects of long-standing underinvestment in agriculture, rural development and food security.

The Declaration of the World Summit on Food Security held at FAO in 2009, stressed the urgent need and concrete actions to promote "new investment to increase sustainable agricultural production and productivity, support increased production and productivity of agriculture", and for the implementation of "sustainable practices, improved resource use, protection of the environment, conservation of the natural resource base and enhanced use of ecosystem services". In this Declaration it is also stated that FAO "will actively encourage the consumption of foods, particularly those available locally, that contribute to diversified and balanced diets, as the best means of addressing micronutrient deficiencies and other forms of malnutrition, especially among vulnerable groups".

Agricultural biodiversity should play a stronger key role in the transition to more sustainable production systems, in increasing production efficiency, and in achieving sustainable intensification. The agriculture sector is responsible for ensuring the production, commercialization and distribution of foods that are nutritionally adequate, safe and environment friendly. Therefore, there is an urgent need to develop and promote strategies for sustainable diets, emphasizing the positive role of biodiversity in human nutrition and poverty alleviation, mainstreaming biodiversity and nutrition as a common path, promoting nutrition-sensitive development and food-based approaches to solving nutrition problems.

The importance of food-based approaches is fully recognized by FAO. Many developing countries, international agencies, non-governmental organizations (NGOs) and donors are beginning to realize that food-based strategies are viable, cost-effective, and provide long-term and sustainable solutions for improving diets and raising levels of nutrition. Narrowing the nutrition gap – the gap between what foods are grown and available and what foods are needed for better nutrition – means increasing the availability, access and actual consumption of a diverse range of foods necessary for a healthy diet. Focusing on the distinctive relationship between agriculture, food and nutrition, FAO works actively to protect, promote and improve established food-based systems as the sustainable solution to ensure food and nutrition security, combat micronutrient deficiencies, improve diets and raise levels of nutrition, and by so doing, to achieve the nutrition-related Millennium Development Goals (MDG).

Globalization, industrial agriculture, rural poverty, population pressures and urbanization have changed food production and consumption in ways that profoundly affect ecosystems and human diets, leading to an overall simplification of diets. High-input industrial agriculture and long-distance transport increase the availability and affordability of refined carbohydrates and fats, leading to an overall simplification of diets and reliance on a limited number of energy-rich foods.

In spite of the increasing acknowledgement of the value of traditional diets, major dietary shifts are currently observed in different parts of the world, representing a breakdown in the traditional food system. This trend has coincided with escalating rates of obesity and associated chronic diseases, further exacerbated by the coexistence of micronutrient deficiencies, owing to the lack of dietary diversity in modern diets. Dietary shifts that have occurred in urban areas are currently extending to rural communities as well, where people have abandoned diets based on locally-grown crop varieties in favour of "westernized" diets.

Your deliberations should, therefore, focus the need for repositioning nutrition security, developing and strengthening food value chains and promoting public/private sector collaborations, with biodiversity and sustainability at its core. The Symposium shall also serve to explore ways in which agricultural biodiversity can contribute to improved food security and to feeding the world within a framework of enhancing agricultural efficiency and ensuring sustainability. I do hope that your collective intellectual wisdom will also offer broad perspectives on ways of changing current global thinking on how to feed the world sustainably and achieve food and nutrition security.

I am sure that the outcome of the Symposium will guide FAO and others in their work towards addressing the role of biodiversity for sustainable food production, in light of global changes.

I once again wish to emphasize that in the current context of difficulties and challenges, it is the shared responsibility of all actors to solve the problems of hunger and degraded ecosystems, and I am convinced that united we can reach the goal of sustainable diets, now and for future generations.

OPENING ADDRESSES

Emile Frison
Director-General Bioversity International
Rome
3 November 2010

I think this Symposium was a very timely one, indeed for the first time in 2010 it would seem that the whole issue of nutrition is reaching a level of awareness in the various sectors, including among donors, not seen before. For too long now the issue of food security has focused on the quantity of food, with very little or no attention given to the quality of food. What really matters is not just filling stomachs but providing a nutritious diet that will allow the cognitive and physical development of human beings. We are aware of the alarming and unacceptable levels of hunger, but the 2 billion people that suffer from malnutrition still do not receive sufficient attention. Expanding exponentially among the world's poorest people and, more than one would believe, among the wealthiest people are cases of micronutrient deficiencies and the double burden of malnutrition with non-communicable diseases. This alarming situation is one that we must tackle together, especially when considering the rate of expansion in the poorest countries.

I am very pleased to see that, through a number of initiatives that have taken place and are taking place in different parts of the world, we are beginning to build this much needed awareness of malnutrition and its devastating impact on the peoples of developing countries. In 2008 Bioversity, together with the Convention on Biological Diversity (CBD) and FAO, launched a cross-cutting initiative on Biodiversity for Food and Nutrition and, more recently, initiatives such as Scaling Up Nutrition have really put the issue of nutrition at the top of the agenda. In New York in September this year, Scaling Up Nutrition was launched by Secretary of State Hillary Clinton and Micheál Martin, Minister for Foreign Affairs of Ireland. I think this shows a real interest up to the highest levels. We must make sure that we seize this opportunity because tomorrow there may be some other hot topic that takes over from nutrition. It is up to all of us to take this momentum that is being built up and move it into action.

When talking about nutrition we must attempt to move beyond the predominant medicalized approach of tackling individual or single micro-nutrient deficiencies or macronutrient deficiencies, attempting to fix the problem after the problem has occurred and with very little effort to prevent the problem in the first place. In order to tackle this issue we should begin looking at malnutrition through food systems, since it is the integration of the entire food system that will provide a sustainable answer to the problems of malnutrition. This Symposium is the right forum for us to do just that.

I believe the true definition of food and nutrition security is that of bringing diverse diets, diets that fulfil all the needs of human beings, to everyone's table. This takes me to the role of agriculture, with nutrition being in the medical camp and agriculture just caring about the quantity of food produced, any links between agriculture and nutrition are weak or totally lacking. We must, as Deputy Director-General of FAO Dr He has already mentioned, prevent the simplification of agriculture to the three major staples. Currently these three major staples provide 60 percent of the calorie intake from plant origin at the global level. Such a degree of diet simplification is alarming and it is high time that we looked not only at producing quantities of food that are sufficient, but also nutrients and nutrition sufficient to fulfill all needs.

I have already mentioned the double burden of malnutrition, this is now becoming the world's number one problem in terms of public health yet it has not been tackled properly nor is it even considered a major problem by many decision-makers. It is up to us now to make sure that this increased attention to nutrition looks at this issue in a holistic way and in a way that will prevent problems in the future.

The organization of the Symposium also coincides with the International Year of Biodiversity. The role that biodiversity can play in addressing the problems of malnutrition has been underestimated, understudied and deserves much more attention. For this reason, this particular Symposium on Biodiversity for Sustainable Diets is very important to me, it is also important that the general public is more aware of the importance of diversity and the potential of biodiversity in addressing the problems of malnutrition. In this regard Bioversity organized, in May of this year, a whole week's celebration: "La Settimana della Biodiversità" here in Rome together with the secretariat of the CBD, IFAD, FAO, the Comune di Roma and many other partners to highlight the importance and raise awareness among the broader public of biodiversity for better nutrition.

There is an urgent need to change the paradigm of agricultural production in order to integrate this dimension of nutritional quality, this requires us to move beyond the major staples and to look at the many hundreds and thousands of neglected and underutilized plant and animal species that mean the difference between an unsustainable and sustainable diet. It is not just about producing calories, but diverse diets and that is why these neglected and underutilized species are so important.

Of course this change will not be successful without collaboration and improved communication among the different sectors. The gap between the agricultural and the nutrition and health sectors must be closed. At a national level (as well as the international level) ministries of agriculture, health, education and of course, ministries of finance must come together to set up and develop policies to address these problems in a sustainable way. There are many examples that show how we at Bioversity have started to try to practise what we preach in looking at neglected and underutilized species. One such example comes from Kenya, where we have been working with leafy green vegetables that have disappeared from the tables and markets in Nairobi. Our aim was to reintroduce these vegetables, to provide nutritious food in supermarkets and markets and to give farmers the opportunity to augment their income. In India, we have been working with the Swaminathan Foundation to look at nutritious millets (foxtail millet, finger millet and others that have various nutritious qualities) and reintroduce them in areas where they had been abandoned due to national policies promoting cassava production for starch. Through analysing the impact of these policies we were able to show that the income derived by the cassava the farmers sold was not sufficient to buy the millet they would have been producing otherwise. What is more, the farmers themselves were consuming the cassava and of course this had a negative impact on their diet. We have been working in the Andes with native cereals, quinoa and amaranth etc., in an effort to improve farming technologies and to allow the production of these nutritious foods to not only be maintained, but to develop further and also enter international markets. These examples and numerous others show that we can make a difference, the simplification of agriculture and the simplification of diets is not something that we just have to accept.

In Kenya, the major obstacle in getting those leafy vegetables onto the tables was one of image, of being considered as backward, and the common conception that this is the food of the poor. However, through communication efforts involving the Minister of Health, the chefs of the most famous restaurants of Nairobi who prepared new recipes with this leafy vegetable and by introducing it in the canteen of parliament, this food has been re-evaluated and people are taking pride again in producing, purchasing and consuming these vegetables. Today production is not sufficient to meet demand, so it is possible to make a difference.

The westernization of diets is not ineluctable; we must also tackle this problem. We have been working for a year or so in preparing for this Symposium together with FAO and many other partners, but this Symposium is not the end of the effort, it is the beginning, unless this Symposium leads to some real action we have not achieved very much. To have a book or a report on a shelf somewhere is not going to fill stomachs and certainly not to feed people better quality food, so we must take this opportunity in various initiatives, such as the Cross Cutting Initiative on Biodiversity for Food and Nutrition and Scaling Up Nutrition, to incorporate the dimension of a diverse diet and the role it can play in improving nutrition.

So this is really the start of, I hope, a major effort to ensure that all people in the world will not only have adequate food but adequate nutrition to meet their needs.

KEYNOTE
PAPER

SUSTAINABLE DIETS AND BIODIVERSITY: THE CHALLENGE FOR POLICY, EVIDENCE AND BEHAVIOUR CHANGE

Tim Lang
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It is a deep honour to address this Symposium with so many distinguished scientists; and always a pleasure for me to be back in Rome where I happily came to live after leaving school. I am a social scientist who is concerned about how policy both shapes and responds to the food system. Here, I want to ask whether policies are currently appropriate for the task of mixing sustainable diets and biodiversity. At present, the answer must be 'no'. Food and agriculture are major drivers of biodiversity loss, which is why this Symposium must help chart a better future. For me, a critical issue worthy of more attention is the definition and pursuit of sustainable diet. What is a good diet in the 21st century? Nutrition science tried throughout the 20th century to clarify what is a good diet for human health. But today it has little or nothing to say so far about how to marry human and eco-systems health.

Here lies a major 21st century food policy challenge. Do I eat ever more meat and/or dairy (an indicator of rising income)? Or do I consume a diet primarily of plants? If I want to eat meat and dairy, what is the right amount, measured against what indicators? And is this the same everywhere? Does embedded water in food make a difference to an acceptable diet? How do I eat nutritionally well while keeping greenhouse gas emissions and embedded water low? And what about fish? Much nutrition science highlights its benefits, yet environmental analysts are concerned about stocks under threat.

These and many other problems lead me to call for a big international effort to define and clarify a 'sustainable diet'. We cannot ignore this challenge. In an ideal world, I'd like to see the creation of something like an Intergovernmental Panel or Special Taskforce on Sustainable Diets. We could also create expert working parties or Commissions. Or ask some representative governments to take a lead. There are many illustrations of processes by which we could begin this process: the IAASTD,[1] the WHO's Commission on Social Determinants of Health,[2] an International Conference such as the 1992 International Conference on Nutrition[3] or the 1992 Rio Conference[4], a committee of experts; or regional rathe than global bodies.
Whichever policy process finally receives backing, the quality of humanity's collective response to the sustainable diet challenge must be raised. And this must begin soon. At present, policy on this issue is a mixture of drifting and fragmenting. Yet if we do not create a policy process to resolve the problem of defining and articulating sustainable diets, there is a real danger that humanity will drift into irreparable damage due to how and what we eat, as incomes rise. The evidence is already too strong about threats to environment,[5] health[6] and social justice.[7] We have to resolve this impasse.

To make matters even more complicated, the challenge of defining sustainable diet is not just a matter of blending two scientific discourses – public health and environment. Food is also a cultural and economic matter. Part of the 20th century's legacy is that it allowed us, in the name of progress, choice and individual rights, to develop an approach to food policy which saw no limits. Old cultural 'rules', sometimes religious, sometimes born from experience, have been weakened by consumerism, enticed by heavily funded marketing. 'Eat this brand not that.' 'Eat what and when you like'. 'Eat high status foods every day all day.' Thus the mismatch of human and environmental health is mediated by economics and culture. There is a push and a pull to this situation; people choose but do not want to accept the longer-term consequences. That is why many people working in this area now see the challenge of sustainable diets as requiring cultural signposts too.

As a Commissioner on the UK government's Sustainable Development Commission (2006-11), I have tried to help my country face this pressing task. In a series of reports, we argued that not only was the issue of sustainable diets our problem in the developed world, but that to include food's environmental footprint in shaping future food supply would help us lead by example, and to 'put our house in order' before lecturing others or leading them to repeat our mistakes. Diet-related ill-health already places a massive burden on the UK's healthcare system. The SDC's sustainable diet study suggested that human and eco-systems goals broadly match.[8] If would be better for UK public health and environment if its citizens ate less much overall (too many people are overweight and obese), less meat and dairy (the burden of non-communicable diseases is high and costly); more fruit and vegetables (which are protective for health). These would also have environmental benefits. While this policy argument has been generally accepted, we know that this now needs to be translated into more specific guidance. Other countries in the European Union have thought likewise : Sweden,[9] Netherlands,[10] Germany[11] In Australia, too, scientific advisors have been tussling with similar problems reviewing their dietary guidelines. Unfortunately, while the evidence that policy needs to address the conundrum of sustainable diets, there are pressures not to face up to the issue.

Alas, my own country's Government closed an Integrated Advice for Consumers programme created to try to resolve the problem of welding health, environment, and social justice in food advice to consumers,[12] and Sweden's advice to environmentally conscious consumers has also been withdrawn after encountering difficulties over whether promoting local foods contravenes EU free movement of goods principles.[13] I report this not to dismiss these fates as 'politics'. Food policy is inevitably highly sensitive. It always was and probably always will be. But everywhere in the world, interest in the issue of sustainable diets is actually growing. The stakes may be high, but that does not mean we must ignore the issue.

What exactly is meant by the term Sustainable Diets? Part of the need to create a proper policy and scientific process is to define it. The word 'sustainability' can be plastic, made to fit many meanings. Mostly, when it is used, it is within the terms laid out in the 1987 Brundtland report,[14] which proposed that human development requires us to give equal weight to the environment, society and economy. This triple focus is not precise enough, I believe. Some argue that we don't even need to define 'sustainable', but merely need to help consumers 'do the right thing'. That was the German and Swedish approach. They appealed to consumers' honour, implying that they were broadly on the right track but needed to have help fine-tuning their choices. The Centre for Food Policy where I work has taken a different direction. We have argued that alongside Brundtland's three factors, the future of food also requires policy attention on quality, health and governance.[15] In my last report as UK Sustainable Development Commissioner, colleagues and I outlined how this new six-headed approach to sustainable food helps include factors which actors throughout the food system know to be important.[16] Under each of these major headings, more specific issues can be grouped. Biodiversity comes under environment, of course.

But the argument for this new six-headed approach to sustainable food and diets is that this should not become a game of 'trade-offs'. As we know over the last thirty years, too often sustainable development has traded off environmental protection for economic development. The value of 'sustainability' is that it gives equal weight to all, not primacy to one focus. We need some rigour from the word sustainable. It must encourage policy-makers to try to deliver a food system which is finely tuned, detailed and accurate about evidence. In the case of the environment, that means not just biodiversity measures, or carbon, but other equally pressing issues such as: water, soil, land use,

And one of the reasons we have argued that health deserves to be one of the new big six headings for sustainable food systems is that health has so easily been lost. Usually it is subsumed within the social. But in food policy, this is not helpful. What is food if not about health for survival? Health is more than safety or minimum requirements; it is also about optimising nutrition, addressing not just dietary deficiencies but dietary excess. 21st century public health now requires a vision for food systems and for food culture which realises the consequences of under-, mal- and over-consumption.

To define sustainable diets thus becomes a key element in recharting the food system for the 21st century. We cannot eat like modern Europeans or North Americans. There are not enough planets. We cannot just pursue increased production at all costs. 21st century food policy needs to face the 'elephant in the room' of consumerism: eating without accepting or paying for the consequences. That is why we need to be wary of trade-offs. Ideal it may be, but the definition of a sustainable diet inevitably shows that all six headings of the new approach need to be addressed: quality, environment, social, health, economic and governance. If specialists or interest groups concerned about one heading do not also take account of the other five, distortions emerge. For example, if the pursuit of cheaper food (a goal actually heavily dependent on fossil fuels) continues to shape rich world food systems, there is an implication that consumers have the right to cheap food. The reality is that the environment is paying. Food economics needs to be brought into line with biodiversity and public health, not continue to distort them.

I see this Symposium as an important step in the process of putting clarity onto the notion of sustainable diets. This meeting and our task of definition is not sudden. It builds directly on work done here in the FAO, such as in the landmark report on the impact of rising animal production, Livestock's Long Shadow [17] It continues in the tradition begun at UNCED / Rio in 1992. We need to dare to do for sustainable diets what has been done for food rights with the landmark 2004 Voluntary Guidelines,[18, 19] and the work of the Special Rapporteur on the Right to Food. That line of assessing food systems and dietary inequality stems from the 1948 Universal Declaration of Human Rights, but really was shaped in the last twenty years, and given weight by the Millennium Development Goals.[20: 281-2] We in this Symposium need to commit to similar diplomatic effort. We too need to aspire to some Guidelines on Sustainable Diet. It took decades to get population-based dietary guidelines shaped by health at national and international levels, but we cannot wait for such slow progress for sustainable diet guidelines, if the environmental and other indicators about diet's impact on the planet are accurate. We urgently need movement.

I do not need to remind a Symposium called by biodiversity experts that modern diets and food production methods are part of the problem of shrinking genetic diversity. 17,291 species out of 47,677 so far assessed are threatened with extinction.[21] But we must not allow ourselves to be mesmerised by a competition as to which heading's figures are worse (or best). The only shocking truth is that a world of plenty has been made which is in danger of undermining itself on a number of fronts, not just one. We meet here in Europe, which prides itself on being civilised, yet Europe's agri-food chain contributes an estimated 18-20% of greenhouse gases and 30% of a consumer's emissions.[22] In the UK, food represents an estimated 23% of a consumer's ecological footprint. We eat as though there are two planets![23] How we eat is altering the web of life, how everything connects, what Charles Darwin called the 'entangled bank' of life.[24]

So, what are the policy goals that ought to shape the food system for the future? Is it to eat what keeps a body optimally healthy? Or to eat what we like? Or to eat within environmental limits? Or to eat according to our income and social status? These are scientific, practical and moral questions. I repeat: my view is that we need to reshape culture around the complexity of meeting multiple goals of quality, environment, health, social, economic and governance. A good food system will strive for improvement across all these, not enter a ruinous competition as to which has the loudest policy voice.

This policy position places responsibilities on scientists too. We / they cannot stay in the comfort zones. Bridges across the disciplines need to be built. Common discourses and research must be created. Policy-makers frequently complain that they cannot get coherence from experts. That may be an excuse for inaction, of course, but there is some truth, too. Too often, experts contribute to what we call 'policy cacophony', many voices all claiming they represent the key issue.[25] In this context, I want to pay respects to pioneering work by some NGOs trying to grapple with this problem. WWF, the conservation organisation has been particularly ambitious in articulating its One Planet Diet programme.[26] Also the Food and Climate Research Network.[27] Some corporations, too, are looking ahead and are troubled by what they rightly see as threats to their long-term profitability and sustainability (in the financial sense of the word). Remarkable commitments are being made: to reduce carbon or water.[28] Sceptics might see this as protecting brands and financial viability. Perhaps, but I think not entirely. Slowly, inexorably, some consensus might be emerging, from different quarters.[29] Everything points to the inevitability of defining sustainable diets and articulating the cultural and policy pathways by which to deliver them.

Discussions I have held with food companies suggest that many are content to address what they see as the environmental challenge of their products through 'choice-editing'. This term is used to mean that they, the companies, shave away the footprint without telling the consumer too much. The change is 'below the parapet' as we say in English. It doesn't confront the consumer with too much radical change. This is interesting and important, not least since it questions how deep the commitment to consumer sovereignty really is. If consumers are not demanding such change, why is it being introduced? Let me be clear. This is a good thing, but it does mean that already the discourse about sustainability and sustainable diets is no longer in the rigid ideological terrain of consumer choice. Changes are being introduced without consumer choice. Indeed, they are restructuring what is meant by choice. These are cautious and hopeful shifts in policy thinking, in advance of most politicians. But I am not alone, as a policy observer, in my concerns about whether there is sufficient urgency. The integration is not there for the whole food system; nor is the required scale and pace of change. No-one is yet leading efforts to change culture rapidly.

If we want consumers to act as food citizens, surely they need help in the form of new, overt 'cultural rules', by which I means guidelines on the 21st century norms of eating. We have quite a range of means by which to do this, from 'hard' such as fiscal and legal measures, to 'soft' ones such as education and labelling. I doubt any system of labelling could capture sustainable dietary advice. Labels have not stopped the nutrition transition. The introduction and design of labels themselves tends to become a battleground, when they ought to be policy means rather than ends.

In conclusion, I believe that the case for the better definition of sustainable diets is overwhelming. There is already sufficient evidence as to food's impact to warrant the creation of comprehensive sustainable dietary guidelines at national, regional and global policy levels. I listed earlier some policy processes which might deliver these: panels, commissions, etc. But we also need to recognise that definitions and guidelines do not engender change on their own. They are means, not ends. External as well as professional pressure to change is essential. It gives policy-makers both support and space to come up with solutions. Pressure to change food systems and policy direction is long overdue. Production focus is no longer a sound or adequate goal for food policy. We need a hard, cold look at the fault-lines and power relations in current policy-making: why some interests triumph. Food raises fundamental questions about humanity's relationship to the planet: is it exploitative or facilitative, democratic or sectional? On the Masters Programme in Food Policy at my University, we frequently give our students an exercise: you have five minutes with the President (or Prime Minister or Sovereign), what will you say? Here is my attempt for the topic we are tussling over.

Firstly, we need to define sustainable diets, urgently. We need to set up a process to do this, perhaps many processes, but these must be formalised. There will be resistance; some companies and institutions are wary, others are overtly hostile, but more are beginning to see the point. They are already engaging about sustainable production, not least since rising oil prices are pushing core costs upwards. This process can and should appeal to the common good. It is among the 21st century's greatest challenges to eat within planetary limits yet giving health, pleasure and cultural identity.

Secondly, we need to clarify where biodiversity fits into sustainable diets. Is the greatest contribution of consumers just to eat less? To eat more simply? To cut out or just down on meat and dairy? To eat the same everywhere? (I doubt it) All year round the same diet? (I doubt it.) But let's explore those questions. Thirdly, we need to ensure appropriate institutional structures. Have our countries, regions and world bodies got the appropriate policy vehicles for these discussions? Can the Convention on Biological Diversity be squared with the advice coming from Health bodies or Trade bodies? Whose processes matter most?

Fourthly, we must research which arguments and factors are most effective in delivering consumer behaviour change. If we do not do that, our fine intentions and evidence on the need to eat sustainably might fail.

Fifthly, we must fuse nutrition and environmental guidelines to generate new cultural rules, to guide everyday norms and habits. Biodiversity protection must be part of that. Nutrition education is currently sadly almost blind to biodiversity, but this need to remain so. Even the countries trying to take a lead on sustainable diets wrap the notion up in the 'soft' language and instruments of choice. They shy away from the real change agents such as fiscal impact on price or regulatory frameworks shifting the 'level playing field' on which business can work. The full range of policy instruments to frame choices isn't being applied. To be stark, the pursuit of sustainable diets is an indicator of progress. It redefines what we mean by progress.

We have much to do. We are not sure about what to do about policy on sustainable diets yet, but we have enough evidence and enough clarity about the criteria by which sustainable diets might be judged to act and to urge policy-makers to have courage to act sooner rather than later.

References

IAASTD, Global Report and Synthesis Report. 2008, International Assessment of Agricultural Science and Technology Development Knowledge: London.

Commission on Social Determinants of Health, Report of the Commission, chaired by Prof Sir Michael Marmot. http://www.who.int/social_determinants/en/. 2008, World Health Organisation: Geneva.

FAO and WHO, International Conference on Nutrition. Final report of the conference. 1992, Food and Agriculture Organisation, and World Health Organisation: Rome.

UNCED, Rio Declaration, made at the UNCED meeting at Rio de Janeiro from 3 to 14 June 1992. 1992, United Nations Conference on Environment and Development: Rio de Janeiro.

UNEP (Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., and B. Svihus, Prins, A. G., Kaltenborn, B. P. (Eds)), The Environmental Food Crisis: The Environment's role in averting future food crises. A UNEP rapid response assessment. 2009, United Nations Environment Programme / GRID-Arendal Arendal, Norway.

WHO, Global strategy on diet, physical activity and health. 57th World Health Assembly. WHA 57.17, agenda item 12.6. 2004, World Health Assembly: Geneva.

De Schutter, O., Reports of the UN Special Rapporteur on the

Right to Food. http://www.srfood.org. 2011, UN Economic and Social Council: Louvain / Geneva.

Sustainable Development Commission, Setting the Table: advice to Government on priority elements of sustainable diets. 2009, Sustainable Development Commission: London.

National Food Administration (of Sweden) and E. Agency, Environmentally effective food choices: Proposal notified to the EU. 2008, National Food Administration: Stockholm.

Health Council of the Netherlands, Guidelines for a healthy diet: the ecological perspective. 2011, Health Council of the Netherlands: The Hague.

German Council for Sustainable Development, The Sustainable Shopping Basked: a guide to better shopping. 3rd edition. 2008, German Council for Sustainable Development: Berlin.

Food Standards Agency IAC Project Team, Integrated advice for consumers: Discussion and analysis of options. www.food.gov.uk/multimedia/pdfs/iacreport.pdf. 2010, Food Standards Agency: London. p. 123.

Dahlbacka, B. and P. Spencer, Sweden Withdraws Proposal on Climate Friendly Food Choices. December 2, 2010. GAIN Report SW1007. 2010, USDA Foreign Agricultural Service Global Agricultural Information Stockholm.

Brundtland, G.H., Our Common Future: Report of the World Commission on Environment and Development (WCED) chaired by Gro Harlem Brundtland. 1987, Oxford: Oxford University Press.

Lang, T., From `value-for-money' to `values-for-money'? Ethical food and policy in Europe. Environment and Planning A, 2010. 42: p. 1814-1832.

Sustainable Development Commission, Looking Forward, Looking Back: Sustainability and UK food policy 2000 – 2011. http://www.sd-commission.org.uk/publications.php?id=1187 2011, Susainable Development Commission: London.

FAO, Livestock's Long Shadow – environmental issues and options. 2006, Food and Agriculture Organisation.: Rome.

FAO, Voluntary Guidelines to support the progressive realization of the right to adequate food in the context of national food security. Adopted by the 127th Session of the FAO Council November 2004. 2004, Food and Agriculture Organisation: Rome.

FAO, Declaration of the High-Level Conference on World Food Security: the Challenges of Climate Change and Bioenergy. June 3-5 2008. http://www.fao.org/fileadmin/user_upload/foodclimate/HLCdocs/declaration-E.pdf. 2008, Food & Agriculture Organisation: Rome.

Lang, T., D. Barling, and M. Caraher, Food Policy: integrating health, environment and society. 2009, Oxford: Oxford University Press.

IUCN., Red List of Endangered Species. http://www.iucnredlist.org/news/vertebrate-story. 2010, International Union for the Conservation of Nature: Gland.

Tukker, A., et al., Environmental Impact of Products (EIPRO): Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. EUR 22284 EN. 2006, European Commission Joint Research Centre.: Brussels.

WWF-UK, Tasting the Future. 2010, ADAS, Food & Drink Federation, Food Ethics Council and WWF: Godalming. p. Tasting t.

Darwin, C., On the origin of species by means of natural selection, or The preservation of favoured races in the struggle for life. 1859, London: John Murray. ix, [1], 502, 32 p., [1] folded leaf of plates.

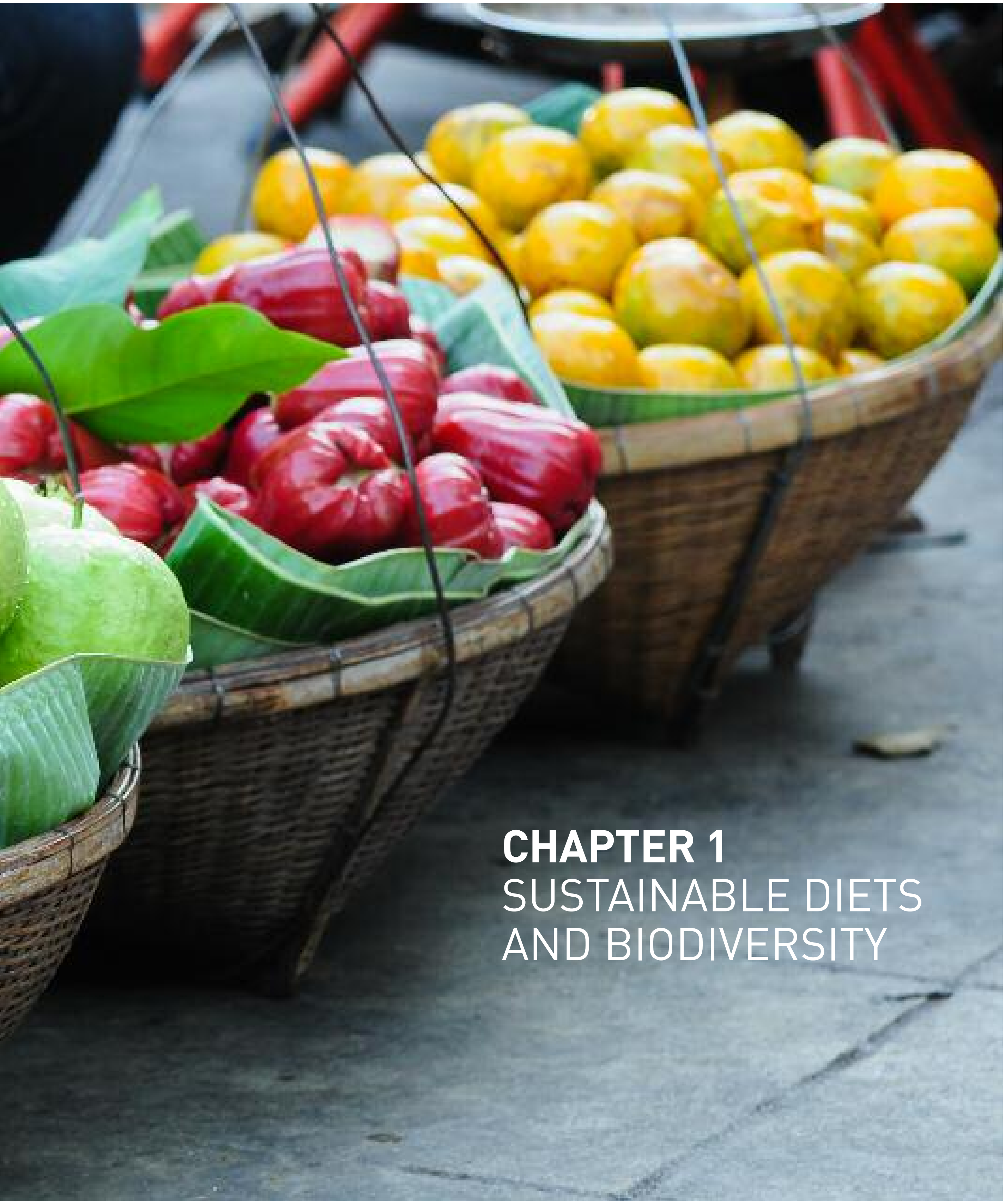
Lang, T. and G. Rayner, Overcoming Policy Cacophany on Obesity: an Ecological Public Health Framework for Politicians. Obesity Reviews, 2007 8(1): p. 165-181.

WWF-UK, One Planet Food Strategy 2009-2012. 2009, WWF UK: Godalming Surrey.

Audsley, E., et al., How Low Can We Go? An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050 2010, FCRN and WWF: Godalming, Surrey.

Unilever, Sustainable Living Plan 2010. http://www.sustainable-living.unilever.com/the-plan/ [accessed December 12 2010]. 2010, Unilever plc: London.

Barilla Centre for Food and Nutrition, Double Pyramid: health food for people, sustainable food for the planet. 2010, Barilla Centre for Food and Nutrition: Parma.



CHAPTER 1
SUSTAINABLE DIETS AND BIODIVERSITY

BIODIVERSITY AND SUSTAINABLE NUTRITION WITH A FOOD-BASED APPROACH

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Abstract
It is time to face the evidence of a worldwide unsustainable food system. Its complexity makes it extremely fragile to any climatic, socio-economic, political or financial crisis. Thus, we urgently need appropriate understanding and new strategies to really accommodate present and future population needs and well-being. In that context, we need sustainable diets, with low-input, local and seasonal agro-ecological food productions as well as short-distance production-consumption nets for fair trade. Cultural heritage, food quality and culinary skills are other key aspects determining sustainable dietary patterns and food security. Nutrition education about appropriate food choices remains essential everywhere. It thus appears very urgent to profoundly change our food strategy and to promote fair, culturally-appropriated, biodiversity-based, ecofriendly, sustainable diets. Authorities should urgently assume their responsibilities by orienting and supporting the appropriate and sustainable foodstuff productions and consumptions in all parts of the world.

1. Introduction

As the President of the Federation of European Nutrition Societies (FENS), gathering national nutrition societies of 24 countries in Europe, I was very pleased to have the FENS as one of the organizations associated to the International Scientific Symposium "Biodiversity and sustainable diets united against hunger", organized at FAO headquarters in Rome, 3–5 November 2010.

At the beginning of this new millennium, we are still facing an alarming challenge. One billion poor people still suffer from hunger and malnutrition while about 2 billion show undernutrition and micronutrient deficiencies (FAO, 2011). At the same time, about 2 billion are overweight and/or obese, a steadily increasing number in all countries in the world (WHO, 2011).

This double burden is found in both poor developing countries as well as in Brazil, Russia, India and China. It is noteworthy that an important fraction of the population in industrialized countries is suffering from poverty too and inadequate food and nutrient intakes. The recent trends for these patterns are quite alarming (CDC, 2011) thus highlighting the overall inadequacy of food supply and dietary patterns during the last decades and present time worldwide. For a few decades only, a multinational, industrial agrofood system developed worldwide that has progressively shifted producer activities as well as consumer demand and attitude. It has been clearly shown that low-cost foods are those energy-dense (fat- and sugar-rich) and nutrient-poor (Maillot *et al.*, 2007), inducing both deficiencies and overweight consequences of inappropriate food choices driven by household income and education level. The drastic changes that recently occurred and presently occur in most countries seem to originate in the erosion of the traditional ways of life and culture as the new "Western/North American" food model and system spreads over the world. This "modern" trend is now clearly facing the challenge of sustainability, both in terms of land use for food production, farmers' income and poverty, water availability, pollution of the environment by chemicals and pesticide residues, fossil energy decline and cost, environment and biodiversity degradation, climate change and global warming. As discussed below, this global challenge (Godfray *et al.*, 2010) urgently needs appropriate understanding as well as new attitudes and appropriate strategies from the research and development sector and stakeholders to really accommodate present and future population needs and well-being.

2. Facing the evidence of an unsustainable food system

Indeed, the present food production, food supply and food consumption system does not generally fit present and future human needs, because it is unable to satisfactorily feed everybody and relies on high fossil energy use, chemicals, and energy inputs, long-distance transport, low-cost human work and cultural loss. It generates both micronutrient and fibre deficiencies as well as excess intakes of fat and sugar promoting overweight and obesity in a general trend of reduced physical activity and body energy expenditure. Food choices and their determinants are in fact central to the present situation. It is well known that they are increasingly driven by the world-wide economic sector through industrialized production simplification, generalized intensive food processing and refining, aggressive food distribution and advertising. In contrast, they are progressively less influenced by the local cultural heritage and a suited integration in the environment.

This very new food system has been developing since the mid-twentieth century, i.e. two human generations ago only, and it is known to generate large greenhouse gas emissions and promote marked alterations of ecosystems such as biodiversity loss, deforestation, soil erosion, chemical contaminations, water shortage. Specifically, it is widely based on a very low diversity of cultivated food crops and cultivars/breeds and an apparent but limited variety of foodstuffs purchased, processed and consumed. Despite an apparent opulence, the complexity of the present food supply system makes it extremely fragile to any climatic, socio-economic, political or as recently financial crisis (Brinkman *et al.*, 2010). This very recently happened with the rice financial crisis with prices increased fourfold in a few months in 2008 highlighting implications of high food prices for global nutrition (Webb, 2010) or with the 2011 earthquake in Japan that emptied food stores within 3 days in highly urbanized areas.

The high energy content of most food consumed can fit the important needs of people with a high energy expenditure but is in excess for most urbanized sedentary people. In addition, the low nutrient/fibre density of generally consumed food (raw and processed) is a widely acknowledged concern in all countries. As an example, the fibre, mineral, vitamin and anti-oxidant content of wholewheat bread compared with refined-wheat bread is about three to fourfold higher for the same amount of energy. The proportion of animal food (especially processed meat and full-fat dairies) is generally in large excess compared to minimal needs and markedly raises the cost of the daily diet (Maillot *et al.*, 2007).

3. An urgent need for sustainable diets

There is thus an urgent need to launch a new strategy to develop the concept and use of sustainable diets in the various contexts of industrialized and developing countries, to ensure food security and quality. Such systems should be based on low-input agro-ecological staple food production including limited animal husbandry, short-distance production-consumption nets, minimal food processing and refining, important culinary skills, diet and nutrition education, and firm links to positive traits of ancestral local cultures as well as appropriate use of recent technology tools. Biodiversity improvement appears to be a key for sustainable food production and food consumption.

3.1 Low-input agro-ecological food production

Since the origin of agriculture until the nineteenth century, the food production systems in very different geo-climatic contexts all over the world were low-input, ecologically integrated by necessity. Impressive skills have been developed over millennia and centuries to adapt to the specific environments and available means, and improve farming methods to sustain human development. While this process allowed the human species survival it was not sufficient to provide anybody appropriate food any time. This facilitated the emergence in the twentieth century of the intensive industrial agriculture system based on high fossil energy and chemical use. Although yields improved in the short term, present limits and persistence of one billion undernourished request new orientations, in the context of the rapid and important increase in the population in some parts of the world. In fact, it has already been advocated through a conference co-organized by FAO (El-Hage Scialabba, 2007) that appropriate agro-ecological food production systems can perform better (around 180%) than agro-industrial ones to provide food to people in developing countries by combining traditional knowledge and skills with more recent concepts and means. This could allow the necessary improvement in staple foods yields in a sustainable way protecting natural and cultivated biodiversity as well as avoiding poisoning of ecosystems and humans. This has again been recognized by the O. De Schutter, UN Special rapporteur on the right to food by stating: "Small-scale farmers can double food production within 10 years in critical regions by using ecological methods. Agro-ecology is an intensive-knowledge approach: it requires public policies supporting agricultural research" (De Schutter, 2011). In industrialized countries, agro-ecological food production systems, generally called "organic" and supported in Europe by the Commission already represent 10 percent or even more of the agricultural sector and prove to be efficient to provide quality food with reasonable yields while respecting environment. It is a sounded approach towards the necessary need to integrate nutrition and ecology (McMichael, 2005).

3.2 Local production and short-distance production-consumption nets

To produce locally most staple food is the best way to ensure food security and to avoid disturbances due to globalization and international uncertainties. In line with the above points, this implies to grow productions in season with minimal inputs to improve sustainability. This would stimulate the search for adapted species and varieties and thus increase cultivated biodiversity.

These seasonally produced foods should be better consumed locally. This will optimize the flavours, tastes and nutritional quality of those foods harvested at top maturity and thus will favour their consumption (especially for fruit and vegetables). Short-distance purchases would limit transportation energy use and direct sales from farmers to consumers through new local organizations is the best way to get good prices in a fair trade as well as knowledge, understanding and confidence, thus the best way to reconcile the urban citizen and producers and be a better part of the whole ecosystem.

3.3 Food quality, culinary skills, dietary patterns and nutrition education

As introduced before, an overall food quality is a prerequisite for an optimal nutrition.

Regarding produced raw food, an optimal quality lies in tasty products, with high nutrient content and no/minimal contaminations by chemical toxicants. The products raised through the agro-ecological methods such as certified organic ones generally fit these two requirements by improving the dry matter and some nutrients contents and minimizing chemical and nitrate contaminations as recently reviewed (Rembialkowska, 2007; FSA, 2009; Lairon, 2010).

Minimal processing can be one of the best ways to keep original flavours and taste, without any need to add artificial flavouring or additives, or too much salt. This would also be the efficient way to keep most nutrients, especially the most sensitive ones such as many vitamins and anti-oxidants. Milling of cereals is one of the most stringent processes which dramatically affect nutrient content. While grains are naturally very rich in micronutrients, anti-oxidants and fibre (i.e. in wholemeal flour or flakes), milling usually removes the vast majority of minerals, vitamins and fibres to raise white flour. Such a spoilage of key nutrients and fibre is no longer acceptable in the context of a sustainable diet aiming at an optimal nutrient density and health protection. In contrast, fermentation of various foodstuffs or germination of grains are traditional, locally accessible, low-energy and highly nutritious processes of sounded interest.

Home processing of food, essentially cooking, is a cultural heritage of all people groups. Given the energy source does not compromise the ecosystem, it allows local preparation of foods of easy digestibility and of variable and enjoyable kinds. Cooking allows the use and mix of a huge variety of foods, herbs and spices. It identifies individuals and people groups around their cultural traditions, skills and way of life. Dietary patterns are acknowledged as the best descriptors of the day life food intake habits and of recommended nutrition guidelines. They can rely more or less on diversity, cultural heritage or healthiness. Overall, some patterns are thought to be rather detrimental such as the "Western diet pattern" which is energy-dense, rich in meats and dairies, saturated fat and sugar and poor in some micronutrients and fibre. Some others of "prudent" type are recommended which are more nutrient-dense and plant foods-based, with plenty of fruit, vegetables, nuts, wholegrains and some fish. In addition, knowledge, concepts and tools are now available to scientifically design the minimal changes necessary in terms of food consumed to make people able to fit the recommended nutrient and fibre intakes necessary to maintain and promote health (Maillot *et al.*, 2010 and 2011). In addition to empirical knowledge and tools, this new approach could help to identify and promote better food choices. Another necessary approach is to analyse the sustainability of dietary patterns in terms of life-cycle assessment and energy and land requirements (Carlsson-Kanyama *et al.*, 2002; Duchin, 2005). In fact, most traditional local dietary patterns are of the "prudent" type, the most famous being the Mediterranean (Willett *et al.*, 1995; Sofi *et al.*, 2008; Bach-Faig *et al.*, 2011) and the Asian ones. Their unfortunate progressive disappearance is associated with the erosion of the local culture and traditional food system, and a key challenge is to stop this negative trend and allow a sounded renewal and updating of such dietary patterns. This is now done with the modern Mediterranean dietary pyramid (Bach-Faig *et al.*, 2011; Reguant-Aleix *et al.*, 2009) which aims to reconcile traditional food productions and way of life with sounded food choices to fulfil nutrient requirements and fit with low energy use and environment and biodiversity protection. Another example comes from Northern Europe where health-promoting and environment friendly regional diets have been designed for Nordic countries (Bere and Brug, 2008).

Information and education about appropriate food choices is thus essential to improve the present situation in all countries given it is within a framework of sustainability, i.e. accounting for nutrition, culture, pleasure, equity, well-being and health, environment and biodiversity protection for all as illustrated in Figure 1.

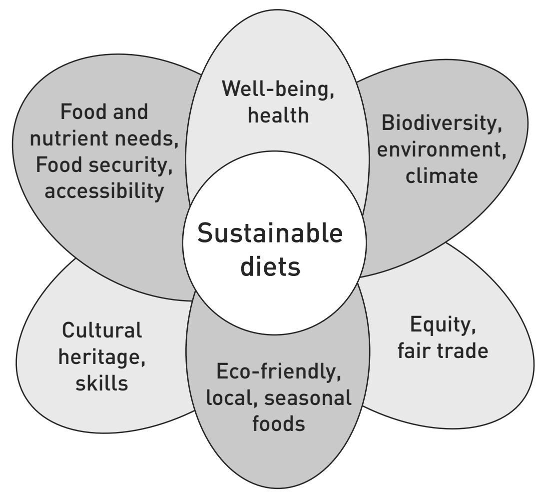

Figure 1. Schematic representation of the key components of a sustainable diet.

4. Conclusion

Somewhat opposite to the present economy, technology and finance domination, examples from agro-ecological local food systems that have the potential to supply people in rural as well as urban areas with appropriate food in terms of quantity and quality should be accounted for. This implies that the worldwide amazing food culture heritage is protected and further optimized to fit new challenges, especially to ensure food security. Appropriate and diversified cultivars or breeds should be cultivated or raised, farming practices should improve biodiversity, protect soil, forest and water, minimize chemical contamination of people and food, sustain ecosystems in the long term and reduce global warming. Authorities should urgently assume their responsibilities by orienting and supporting the appropriate and sustainable foodstuff productions and consumptions.

Food and diets are among the key social determinants of health and well-being, but the present food system is profoundly unfair and generates social injustices. From the past half-century experiences and present trends, we are convinced that it becomes very urgent to profoundly change our food strategy and to promote fair, culturally-appropriated, biodiversity-based, sustainable diets. This is indeed a considerable challenge for nutritionists too.

References

Bach-Faig, A., Berry, E., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., Burlingame, B., Medina, F.X., Battino, M., Miranda. G., Serra-Majem, L., on behalf of the Mediterranean Diet Foundation Expert Group (2011). Mediterranean diet pyramid today. Science and cultural updates. Public Health Nutrition, in press.

Bere, E., Brug, J. (2008). Towards health-promoting and environment friendly regional diets, a Nordic example. Public Health Nutrition, 12 (1), 91-96.

Brinkman, H.J., de Pee, S., Sanogo, I., Subran, L., Bloem, M.W.(2010). High food prices and the global financial crisis have reduced access to nutritious food and worsened nutritional status and health. Journal of Nutrition, 140(1):153S-61S.

Carlsson-Kanyama, A., Pipping Ekström, M., Shanahan, H. (2002). Food and life cycle energy imputs: consequences of diet and ways to increase efficiency. Ecological Economics, 44, 293-307.

CDC, Center for Disease Control (2011).
Accessible at http://www.cdc.gov/DiseasesConditions.

De Schutter, O. (2011). Report, March 8, Geneva,. Accessible at http://www2.ohchr.org/english/issues/food/annual.htm

Duchin, F. (2005). Sustainable consumption of foods. A framework for analysing scenarios about chnages in diet. Industrial Ecology, 9, 99-114.

El-Hage Scialabba, N. (2007). Organic agriculture and food security, Food and Agriculture Organization of the United Nations, Report of the International conference on organic agriculture and food security, May 3-5, Roma, Italy, 22p. (available at http://www.fao.org).

FAO, Food and Agriculture Organization of the United Nations. (2011). Accessible at http://www.fao.org/hunger.

FSA, Food Standards Agency (UK). Comparison of composition (nutrients and other substances) of organically and conventionally produced foodstuffs : a systematic review of available literature. 2009, 31 pages. Accessible at http://www.food.gov.uk.

Godfray, H.C., Beddington.J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J. H., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C.(2010). Food security: the challenge of feeding 9 billion people. Science, 327(5967):812-8.

Lairon, D.(2010). Nutritional quality and safety of organic food. A review. Agronomy for Sustainable Development, 30: 33-41.

Maillot, M., Darmon, N., Darmon, M., Lafay, L., Drewnowski, A. (2007). Nutrient-dense food groups have high energy costs: an econometric approach to nutrient profiling. Journal of Nutrition, 137(7):1815-20.

Maillot, M., Vieux, F., Amiot, J., Darmon, N. (2010). Individual diet modeling translates nutrient recommendations into realistic and individual-specific food choices. American Journal of Clinical Nutrition, 91:421-30.

Maillot, M., Issa, C., Vieux, F., Lairon, D., Darmon, N.. The shortest way to reach nutritional goals is to adopt Mediterranean food choices. (2011) Evidence from computer-generated personalized diets. American Journal of Clinical Nutrition, in press.

McMichael, A., J. (2005). Intergating nutrition with ecology: balancing the health of humans and biosphere. Public Health Nutrition, 8, 706-715.

Millward, D.J., Garnett, T. (2009). Food and the planet: nutritional dilemmas of greenhouse gas emission reductions through reduced intakes of meat and dairy foods. Proceedings of the Nutrition Society, 69, 1-16.

Reguant-Aleix, J., Arbore, M.R., Bach-Faig, A., Serra-Majem, L. (2009). Mediterranean heritage: an intangible cultural heritage. Public Health Nutrition, 12:1591-4.

Rembialkowska, E. (2007). Quality of plant products from organic agriculture. Journal of Science of Food and Agriculture, 87, 2757-2762.

Sofi, F., Cesari, F., Abbate, R., Gensini, G.F., Casini, A. (2008). Adherence to Mediterranean diet and health status: meta-analysis. British Medical Journal 337:a1344. doi: 10.1136/bmj.a1344.

Webb, P. (2010). Medium to long-run implications of high food prices for global nutrition. Journal of Nutrition, 140, 143S-147S.

WHO, World Health Organization of the United Nations. (2011). Accessible at
http://www.who.int/mediacentre/factsheets/fs311/en/index.html

Willett, W.C., Sacks, F., Trichopoulou, A. et al. (1995). Mediterranean diet pyramid: a cultural model for healthy eating. American Journal of Clinical Nutrition, 61:1402S-6S.

BIODIVERSITY, NUTRITION AND HUMAN WELL-BEING IN THE CONTEXT OF THE CONVENTION ON BIOLOGICAL DIVERSITY

36

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1. The interlinkages between biodiversity and human well-being

Biological diversity, known as biodiversity, underpins the well-being of society. The poor, who depend disproportionately on biodiversity for their subsistence needs, suffer first and most severely from its degradation, but we all ultimately rely on biodiversity. Growing recognition of the links between ecosystem services and human well-being (Figure 1).

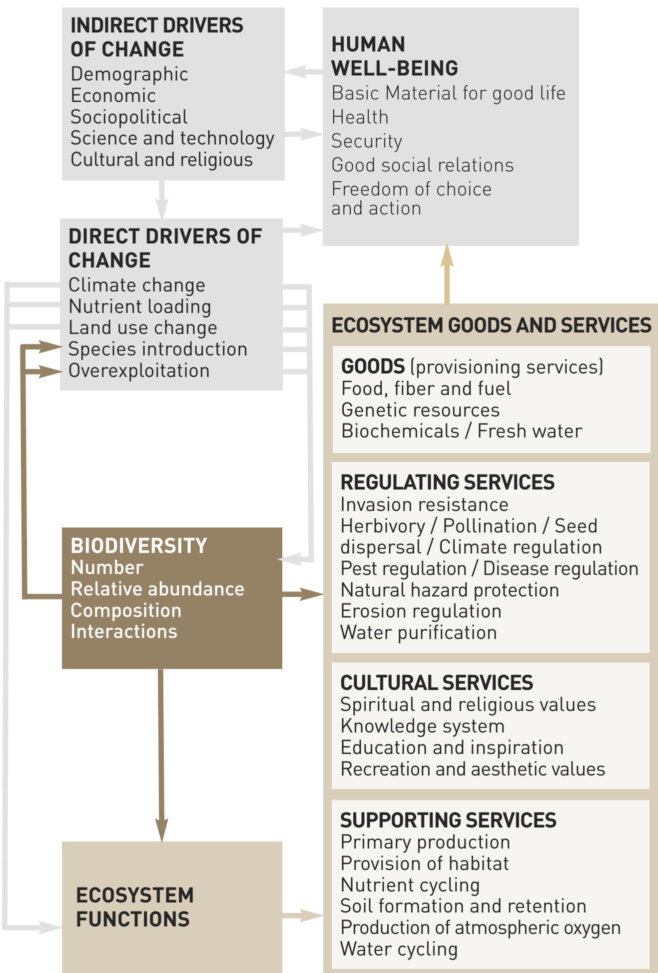

Figure 1. Biodiversity is affected by drivers of change and also is a factor modifying ecosystem function. It contributes directly and indirectly to the provision of ecosystem goods and services. These are divided into four main categories by the Millennium Ecosystem Assessment: goods (provisioning services) are the products obtained from ecosystems; and cultural services represent non-material benefits delivered by ecosystems. Both of these are directly related to human well-being. Regulating services are the benefits obtained from regulating ecosystem processes. Supporting services are those necessary for the production of all other ecosystem services (Secretariat of the Convention on Biological Diversity, 2006).

implies that biodiversity should be a priority in national and international efforts to address health and well-being, including nutrition and food security, as well as gender equity and poverty reduction in the context of sustainable development. However, this is often not the case and the continuing failure to recognize the value of biodiversity and its role in underpinning ecosystem services is rapidly pushing us towards critical tipping points, where many ecosystems risk shifting into new states in which the capacity to provide for the needs of present and future generations is highly uncertain. Actions taken over the next two decades will determine whether the relatively stable environmental conditions on which human civilization and well-being depends may continue beyond this half century.

2. The 2010 targets and the status of biodiversity

In April 2002, the Parties to the Convention on Biological Diversity (CBD) (see www.cbd.int for further information) agreed "to achieve, by 2010, a significant reduction in the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth". This pledge was subsequently endorsed by the World Summit on Sustainable Development in Johannesburg later in 2002, and by the UN General Assembly, as well as being incorporated as a new target within the Millennium Development Goals (Goal 7b).

The final review of progress towards the 2010 target was undertaken as part of the third edition of the Global Biodiversity Outlook (GBO-3) (Secretariat of the Convention on Biological Diversity, 2010). GBO-3 concluded that the 2010 target had not been met at the global level, despite the many actions taken in support of biodiversity, as the actions were not of a sufficient scale to address the pressures on biodiversity in most places.

Of the headline indicators used to assess progress towards the 2010 target, ten show trends unfavourable for biodiversity, while three show no clear global trend and only two show positive trends (Figure 2).

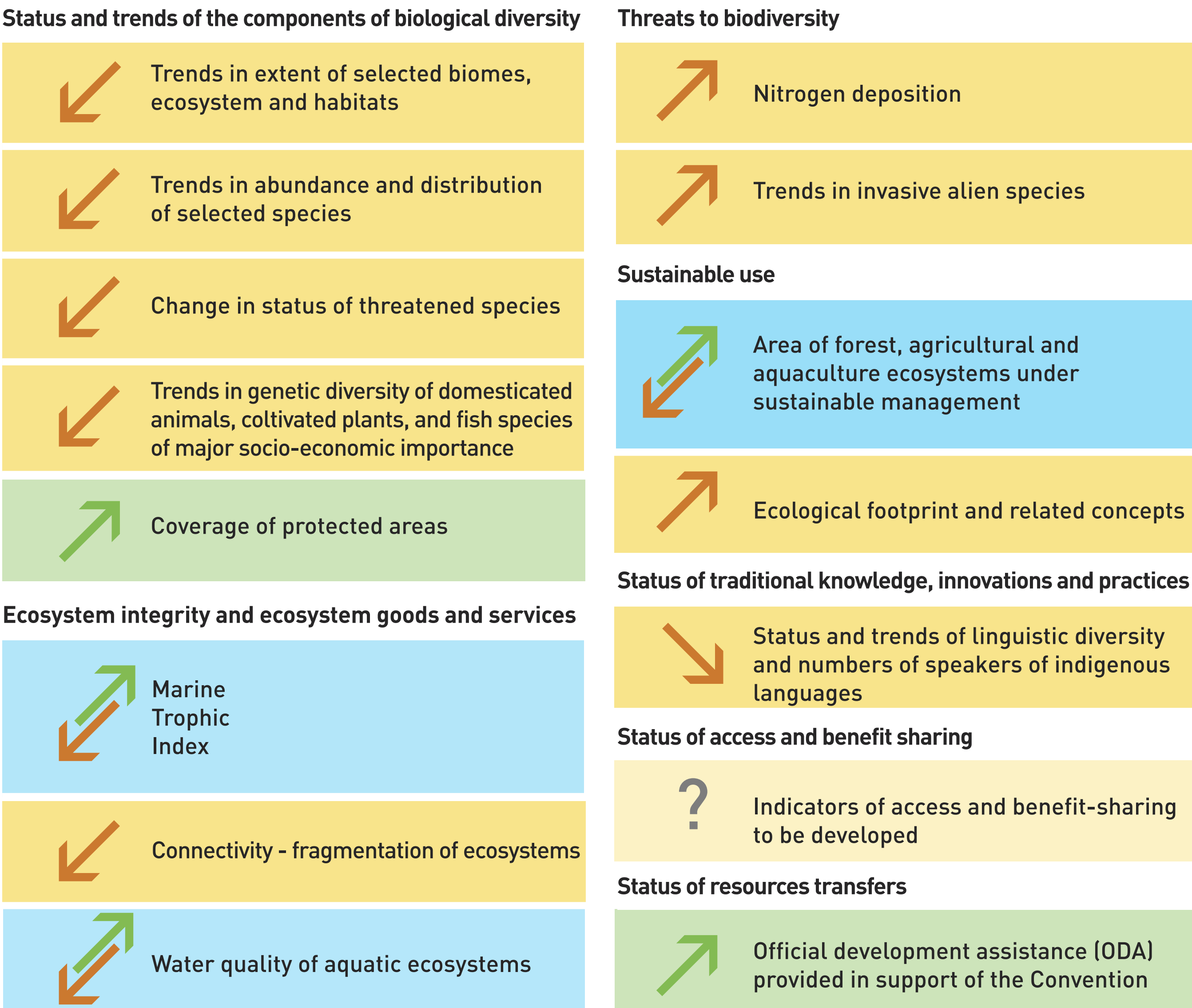

Figure 2. Trends of headline indicators of the 2010 biodiversity target with indicators of particular relevance to food and nutrition highlighted in red boxes (Secretariat of the Convention on Biological Diversity, 2010).

3. Future scenarios for global biodiversity and impacts for health

To examine different possible futures, GBO-3 examined available models that project the likely outcome of differing trends for biodiversity in the coming decades, and reviewed their implications for human societies. Three of the main conclusions from the analysis are that the projected impact of global change on biodiversity shows continuing and often accelerating species extinctions, loss of natural habitat, and changes in the distribution and abundance of species, species groups and biomes over the twenty-first century; secondly, there is a high risk of dramatic biodiversity loss and accompanying broad range of ecosystem services if the Earth's systems are pushed beyond certain tipping points (Figure 3); and thirdly, the study concludes that biodiversity loss and ecosystem changes could be prevented, significantly reduced or even reversed, if strong action is applied urgently, comprehensively and appropriately, at international, national and local levels.

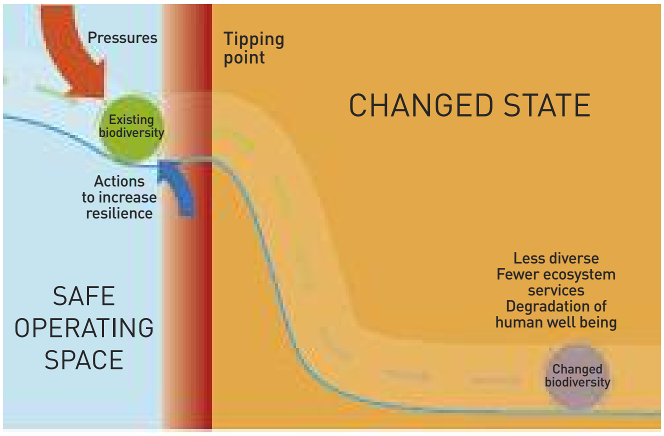

Figure 3. The mounting pressures on biodiversity risks pushing some ecosystems into new states, with severe ramifications for human well-being as tipping points are crossed. While the precise location of tipping points is difficult to determine, once an ecosystem moves into a new state it can be very difficult, if not impossible, to return it to its former state (Secretariat of the Convention on Biological Diversity, 2010).

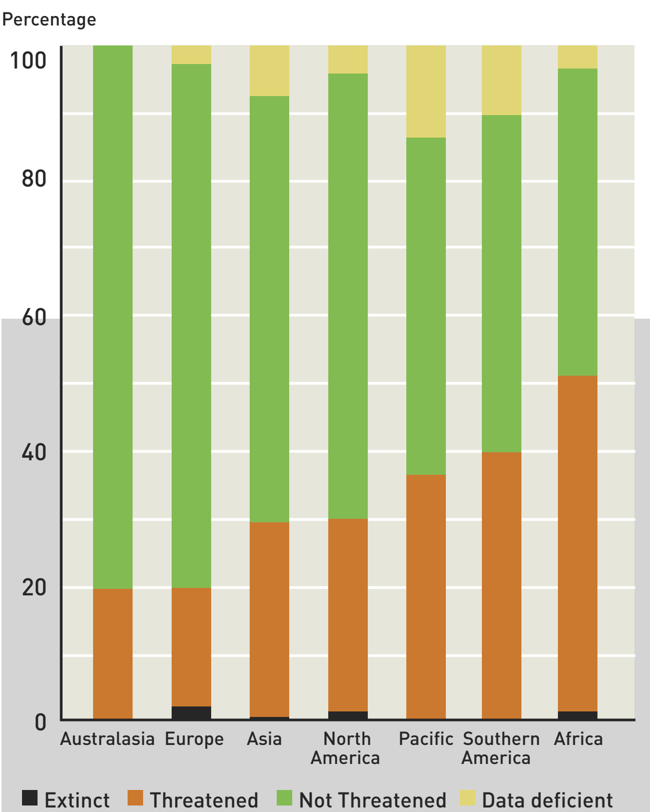

Figure 4. Conservation status of medicinal plant species in different geographic regions. The greatest risk of extinction occurs in those regions where medicinal plants are most widely used (Secretariat of the Convention on Biologival Diversity 2010 adapted from Vié *et al.*, 2008).

4. What does this mean for global food security and health?

Ecosystems around the world are becoming increasingly fragmented and species used for food and medicine are at an increasing risk of extinction (Figure 4). In addition to fragmentation, the degradation of freshwater, marine and terrestrial ecosystems is also a threat to food security. For example, the world's fisheries employ approximately 200 million people and provide about 16 percent of the protein consumed worldwide. However, almost 80 percent of the world marine fish stocks, for which assessment information is available, are fully exploited, overexploited, depleted or recovering from depletion (FAO Fisheries and Aquaculture Department, 2009). While the average maximum size of fish caught has declined by 22 percent since 1959 globally for all assessed communities and, in addition, there is an increasing trend of stock collapses over time, with 14 percent of assessed stocks collapsed in 2007 (Worm *et al.*, 2009).

Over the period 1980–2003, nearly one-quarter (24%) of the world's land area was undergoing degradation, as measured by a decline in primary productivity. Degrading areas included around 30% of all forests, 20% of cultivated areas and 10% of grasslands. Around 16% of land was found to be improving in productivity, the largest proportion (43%) being in rangelands. The areas where a degrading trend was observed barely overlapped with the 15% of land identified as degraded in 1991, indicating that new areas are being affected and that some regions of historical degradation remain at low levels of productivity (Bai *et al.*, 2008).

In addition to the decline in species populations, there is also a decline in genetic diversity in natural ecosystems and in systems of crop and livestock production. The decline in species populations, combined with the fragmentation of landscapes, inland water bodies and marine habitats, have led to an overall significant decline in the genetic diversity of life on Earth (Figure 5).

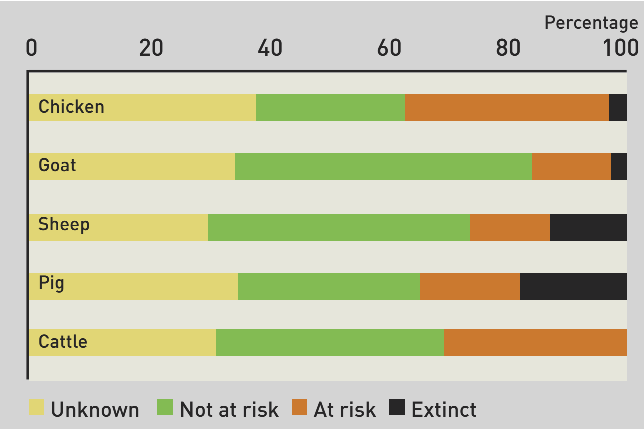

Figure 5. Large numbers of breeds of the five major species of livestock are at risk from extinction. More generally, among 35 domesticated species, more than one-fifth of livestock breeds, are classified as being at risk of extinction (FAO, 2007).

While this decline is of concern for many reasons, there is particular anxiety concerning the loss of diversity in the varieties and breeds of plants and animals used to sustain human livelihoods.

The reduction in the diversity of breeds has so far been greatest in developed countries, as widely-used, high-output varieties have come to dominate. However, the general homogenization of landscapes and agricultural varieties can make the food security of poor and marginalized populations vulnerable to future changes. For example, it is estimated that 21 percent of the world's 7 000 livestock breeds (amongst 35 domesticated species of birds and mammal) are classified as being at risk, and the true figure is likely to be much higher as a further 36 percent are of unknown risk status (FAO, 2007). More than 60 livestock breeds are reported to have become extinct during the first six years of this century alone (FAO, 2007).

In many developing countries, changing market demands, urbanization and other factors are leading to a rapid growth of more intensive animal production systems. This has led to the increased use of non-local breeds, largely from developed countries, and it is often at the expense of local genetic resources. In addition, the cross-breeding of indigenous and imported breeds is also leading to the loss of genetic diversity. For example, in Thailand, with the import of foreign breeds of livestock, indigenous breeds such as the Khaolamppon cow (species name 1), the Rad pig (species name 2), the Hinan pig (species name 3) and the Nakornpratom duck (species name 4) are disappearing (Office of Natural Resources and Environmental Policy and Planning, 2009), while in China there has been a decline in the number of local rice varieties from 46 000 in the 1950s to slightly more than 1 000 in 2006 (Chinese Ministry of Environmental Protection, 2008).

In addition to biodiversity providing food for human health, biodiversity underpins the functioning of the ecosystems which are responsible for providing freshwater, regulating climate, floods and diseases; providing recreational benefits as well as fibres, timbers and materials; aesthetic and spiritual enrichment; and supporting services such as soil formation, pollination, photosynthesis and nutrient cycling (Millennium Ecosystem Assessment, 2005). Biodiversity also contributes to local livelihoods, medicines (traditional and modern) and economic development. Ultimately, all human health depends on ecosystem services that are made possible by biodiversity. In this way, biodiversity can be considered as the foundation for human health and thus, biodiversity conservation, the sustainable use of biodiversity and the equitable sharing of its benefits is a global responsibility at all levels and across all sectors.

Previous actions in support of biodiversity have generally focused on addressing the direct pressures causing its loss and on intervening directly to improve the state of biodiversity, for example in programmes to protect particular endangered species. An estimated 80 percent of Parties reported in their fourth national reports to the CBD that biodiversity was important for human well-being in their country including, amongst other things, as a source of food. However, there has been limited action to address the underlying causes or the indirect drivers of biodiversity loss, such as demographic change, consumption patterns or the impacts of increased trade. Equally, action has tended not to be focused specifically on protecting, and promoting, the benefits provided by ecosystems. The responses from now on should target these neglected aspects of biodiversity loss, while continuing to reduce direct pressures and intervening to protect threatened species and ecosystems.

5. Response of the Parties to the Convention on Biological Diversity

At its tenth meeting of the Conference of the Parties (COP 10), held in Nagoya, Japan in October 2010, the Parties to the CBD adopted a new ten-year Strategic Plan for Biodiversity to guide international and national efforts. The vision of this Strategic Plan is a world "living in harmony with nature" where "by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people".

The Strategic Plan includes 20 headline targets, known as the "Aichi Biodiversity Targets", which are organized under five strategic goals of 1) addressing the underlying causes of biodiversity loss 2) reducing the pressures on biodiversity 3) safeguarding biodiversity at all levels 4) enhancing the benefits for all provided by biodiversity, and 5) enhancing implementation including by providing for capacity-building.

Most of the Aichi Biodiversity Targets have indirect links to food, nutrition and sustainable diets. The following are particularly relevant:

a) Target 3: By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied [...]. Fishery subsidies that contribute to overfishing globally are potential areas for reform as is the continued and deepened reform of production-inducing agricultural subsidies. Bearing in mind the principle of common but differentiated responsibilities, this target does not imply a need for developing countries to remove subsidies that are necessary for poverty reduction programmes.

b) Target 4: By 2020, at the latest, governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption [...]. Reducing total demand and increasing efficiency will contribute to the target and can be pursued through each production- and consumption-related sector, including agriculture and fisheries, developing and implementing plans for this purpose.

c) Target 6: By 2020, all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem-based approaches [...]. Better management of harvested marine resources is needed to reduce pressure on marine ecosystems and to substantially diminish the likelihood of fishery collapses and hence better support food security.

d) Target 7: By 2020, areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity. The ecologically unsustainable consumption of water, use and run-off of pesticides and excess fertilizers, and the conversion of natural habitats to uniform monocultures, amongst other factors, have major negative impacts on biodiversity inside and outside of agricultural areas. On the other hand, sustainable agricultural areas not only contributes to biodiversity conservation but can also deliver benefits to production systems in terms of services such as soil fertility, erosion control, enhanced pollination and reduced pest outbreaks, as well as contributing to the well-being and sustainable livelihoods of local communities engaged in the management of local natural resources.

e) Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity. While substantial progress has been made in safeguarding many varieties and breeds through *ex situ* storage in gene banks, less progress has been made *in situ*.

In situ conservation, including through continued cultivation on farms, allows for ongoing adaptation to changing conditions (such as climate change) and agricultural practices.

f) Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded [...]. Ecosystem services related to the provision of water and food are particularly important in that they provide services that are essential for human well-being. Accordingly, priority should be given to safeguarding or restoring such ecosystems, and to ensuring that people, especially women, indigenous and local communities and the poor and vulnerable, have adequate and secure access to these services.

g) Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through restoration of at least 15 percent of degraded ecosystems [...]. Deforestation and other habitat changes lead to the emission of carbon dioxide, methane and other greenhouse gases. However, restored landscapes and seascapes can improve ecosystem resilience and contribute to climate change adaptation, while generating additional benefits for people, in particular indigenous and local communities and the rural poor. Consolidating policy processes and the wider application of these efforts could deliver substantial co-benefits for biodiversity and local livelihoods.

The Aichi Biodiversity Targets are an overarching framework on biodiversity not only for the biodiversity-related conventions, but for the entire United Nations system. Parties to the CBD agreed at the COP 10 meeting to utilize the flexible framework provided by the Strategic Plan for Biodiversity to set their own targets and incorporate these into national biodiversity strategy and action plans (NBSAPs) within two years, taking into account national needs and priorities and also bearing in mind national contributions to the achievement of the global targets (see decision X/2). Additionally, in decision X/10, the COP 10 meeting decided that the fifth national reports, due by 31 March 2014, should focus on the implementation of the 2011–2020 Strategic Plan and progress achieved towards the Aichi Biodiversity Targets.

The opportunity for urgent and sustained action towards implementation of the Strategic Plan for Biodiversity was also reflected in a number of other COP 10 decisions (see Programme of Work on Agricultural Biodiversity decision X/34) in which the COP acknowledged the importance of agrobiodiversity including underutilized crops for food security and nutrition, especially in the face of climate change and limited natural resources; the need to conserve *in situ* and *ex situ* genetic diversity/resources, species and ecosystems/habitats in adequate quantity and quality that are important for food production; the opportunity to better use food, agroecosystems and natural systems sustainably; possibilities for rehabilitation/restoration of agricultural ecosystems and landscapes; strengthening of approaches which promote the sustainability of agricultural systems and landscapes, such as Globally Important Agricultural Heritage Systems (GIAHS) and those in the Satoyama Initiative (Decision X/32), which aim to maintain and rebuild "socio-ecological production landscapes (SEPLs)" that include villages, farmland, adjacent woods, grassland and coasts for the benefit of biodiversity and human well-being; promoting public awareness of the importance of agricultural biodiversity and its relationship to food security. While, as part of the Mountain Biodiversity programme of work COP 10 noted the need to periodically collect and update information on genetic resources, particularly those related to food and agriculture (Decision X/30).

In addition, as part of the development and implementation of its access and benefit-sharing legislation or regulatory requirements, each Party shall consider the importance of genetic resources for food and agriculture and their special role for food security (see Nagoya Protocol on Access and Benefit Sharing, Article 8c. Special Considerations). Food, and food security, is one of the possible non-monetary benefits

that can be equitably shared.
COP 10 also examined the conservation and sustainable use of bushmeat (Decision X/32), while taking into consideration Article 10c as related to customary sustainable hunting practices for the livelihoods of indigenous and local communities and noted, amongst other aspects, that there is a need to develop options for small-scale food and income alternatives in tropical and sub-tropical countries based on the sustainable use of biodiversity in order to support current and future livelihood needs and food security.

6. Conclusions

For millennia, people's use of biodiversity and ecosystem services has contributed to human health and development. Biodiversity is crucial due to the services it provides for our well-being. Sustainable development relies on biodiversity therefore development strategies that undermine biodiversity are counterproductive for poverty alleviation and human well-being.
The recognition of the links between biodiversity, sustainability and human health present a significant challenge to current paradigms in many sectors. In support of the urgent need for action at all levels, the United Nations General Assembly, in Resolution 65/161, proclaimed the period from 2011 to 2020 as the United Nations Decade on Biodiversity.
Biodiversity loss is not a separate issue from the core concerns of society, including issues of nutrition, food security and sustainable development.
The current trends in biodiversity conservation and ecosystem services undermine these global goals and will impact on achievement of the Millennium Development Goals. With adequate resources and political will, this generation can take active steps to implement the Strategic Plan for Biodiversity and simultaneously contribute to achievement of the Millennium Development Goals of eradicating extreme poverty and hunger (goal 1) and ensuring environmental sustainability (goal 7); hence sustaining a healthy planet and benefits for all people.

References

Bai Z.G., Dent D.L., Olsson L. and Schaepman M.E. 2008. Global assessment of land degradation and improvement. 1. Identification by remote sensing. Report 2008/01, ISRIC – World Soil Information, Wageningen. http://www.isric.org/isric/webdocs/docs/Report%202008_01_GLADA%20international_REV_Nov%202008.pdf

Chinese Ministry of Environmental Protection 2008. China's Fourth National Report on Implementation of the Convention on Biological Diversity. http://www.cbd.int/doc/world/cn/cn-nr-04-en.pdf

FAO 2007. The State of the World's Animal Genetic Resources for Food and Agriculture, edited by Barbara Rischkowsky & Dafydd Pilling. Rome.
http://www.fao.org/docrep/010/a1250e/a1250e00.htm

FAO Fisheries and Aquaculture Department 2009. The State of the World Fisheries and Aquaculture. Food and Agriculture Organization of the United Nations.
Rome. ftp://ftp.fao.org/docrep/fao/011/i0250e/i0250e.pdf)

Millennium Ecosystem Assessment 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.
http://www.millenniumassessment.org/documents/document.356.aspx.pdf

Office of Natural Resources and Environmental Policy and Planning. 2009. Thailand: National Report on the Implementation of the Convention on Biological Diversity. Ministry of Natural Resources and Environment, Bangkok, Thailand.
https://www.cbd.int/doc/world/th/th-nr-04-en.pdf

Secretariat of the Convention on Biological Diversity 2006. Global Biodiversity Outlook 2. Montréal. http://www.cbd.int/gbo2/

Secretariat of the Convention on Biological Diversity 2010. Global Biodiversity Outlook 3. Montréal. http://www.cbd.int/gbo3/

Vié J.-C., Hilton-Taylor C. and Stuart S. N. (eds). The 2008 review of the IUCN Red List of Threatened Species. Gland, Switzerland: IUCN.

Worm B., Hilborn R., Baum J.K., Branch T.A., Collie J.S., Costello C., Fogarty M.J., Fulton E.A., Hutchings J.A., Jennings S., Jensen O.P., Lotze H.K., Mace P.M, McClanahan T.R, Minto C., Palumbi S.R., Parma A.M., Ricard D., Rosenberg A.A., Watson R., and Zeller D. 2009. Rebuilding Global Fisheries. Science, 325(5940), 578-585.
http://www.sciencemag.org/cgi/content/short/325/5940/578

ENSURING AGRICULTURE, BIODIVERSITY AND NUTRITION REMAINS CENTRAL TO ADDRESSING THE MDG1 HUNGER TARGET

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Abstract
With less than five years left to accomplish the Millennium Development Goals (MDGs), it is with great hope that nutrition remains a central theme in achieving them. One of the targets of the first MDG is to reduce the proportion of people who suffer from hunger by half between 1990 and 2015, with hunger measured as the proportion of the population who are undernourished and the prevalence of children under five who are underweight. In low and middle income countries progress has been mixed. With one billion people hungry, 129 million and 195 million children are underweight and stunted respectively. Of the 117 countries analysed by UNICEF in late 2009, 63 are on track to meet the MDG1 target based on the proportion of children underweight. From this review, most strategies being implemented and scaled are focused on the direct nutrition-specific interventions – critically important and necessary. However the "nutrition-sensitive" interventions are less clear, particularly those in agriculture and agricultural biodiversity. This review provides an overview of the role of agricultural biodiversity in food and nutrition systems and its potential importance in addressing the determinants of malnutrition and a road to sustainable progress in achieving MDG1 and beyond. Integrating agriculture and agricultural biodiversity practices with broader nutrition-sensitive interventions to address underlying causes of nutrition insecurity is critical for generating durable and longer-term gains. Such an approach would inherently build on the knowledge and capacities of local communities to transform and improve the quality of diets for better child health and nutrition. Success in achieving the MDG1 hunger target will hinge on addressing the root causes of poor nutrition – through evidence-based and contextually relevant food system approaches that can rapidly be taken to scale.

Poverty reduction goals that the world agreed upon: The Millennium Development Goals
At the Millennium Summit in September 2000 the largest gathering of world leaders in history adopted the UN Millennium Declaration, committing their nations to a bold global partnership to reduce extreme poverty and to address a series of time-bound health and development targets. Among these MDGs is a commitment to reduce the proportion of people who suffer from hunger by half between 1990 and 2015. In 2011, some countries remain far from reaching this target, and ensuring global food security persists as one of the greatest challenges of our time. In the developing world, reductions in hunger witnessed during the 1990s have recently been eroded by the global food price and economic crises.

There are currently an estimated 925 million people suffering food and nutrition insecurity; however with food price increases, these estimates may be conservative (FAO, 2010). In addition to those who are hungry, there are also 195 million children under five years of age who are stunted and of those children, 90 percent live in just 36 countries. Malnutrition takes its toll; it is responsible for 35 percent of all child deaths and 11 percent of the global disease burden. Micronutrient deficiencies, known as hidden hunger, undermine the growth and development, health and productivity of over two billion people. At the same time, an estimated one billion people are overweight and another 300 million are obese in both the developed and developing world (WHO, 2006) which contributes to non-communicable disease risk such as diabetes and heart disease. With over-nutrition, many countries and urban communities in the developing world are experiencing the nutrition transition – going from undernutrition to obesity caused by insufficient exercise, sedentary lifestyles and unhealthy diets (Popkin, 2008).

Global, regional and national progress towards the MDG1 hunger target
One of the objectives in defining the MDGs was to create targets and objective indicators that could be

used to set benchmarks and monitor country-level progress. The MDG1 hunger target has two specific indicators: the prevalence of underweight children under five years of age, and the proportion of the population below a minimum level of dietary energy consumption.

In the developing world, the proportion of children under five years of age who were underweight, currently 129 million, declined from 31% to 26% between 1990 and 2008 (based on a subset of 86 countries with trend data for the period 1990 and 2008, covering 89 percent of the developing world's population). The average annual rate of reduction (AARR) of underweight is based on multiple data estimates available from 1990 to 2008 with the AARR needed to achieve a 50% reduction over a 25-year period (1990 to 2015). The rate of change required to achieve the goal is a constant 2.8% reduction per year for all countries. As of 2005, the AARR was at 1.4% per year which would reduce the proportion of children underweight by 37% by 2015. This progress is still insufficient to meet the goal of cutting underweight prevalence by half globally. When taking the recent crises into account, the task will be more difficult, but not unachievable in some countries.

Progress on the prevalence of underweight children
Among low and middle income countries, the greatest declines in the prevalence of children who are underweight have been in the regions of Central and Eastern Europe-Commonwealth of Independent States, East Asia and the Pacific with many countries in all three regions on track to reach the MDG target, in a large part due to progress in China. Latin America and the Caribbean also made progress, with levels declining from 11% to 6% between 1990 and 2008, with Mexico seeing major improvements in children who are underweight. In the Near East and North Africa, the prevalence of children who are underweight has remained roughly the same from 16% to 14% from 1990 to 2008. The stagnation in this region is primarily driven by the situation in Sudan and Yemen. The data also indicated that those living in cities were twice less likely to be underweight than children in rural areas. In South Asia, the prevalence of children who are underweight declined from 54% to 48% between 1990 and 2008, but with such high prevalence levels, attaining the target will be very difficult. In India, progress has been slow, and the country has the highest number of children who are stunted. There have been small improvements in sub-Saharan Africa, but the level of decline is too slow to meet the MDG target. Prevalence has decreased from 32% to 26% from 1990 to 2008. Most of the children who are underweight live in South Asia and Africa.

Of the 117 countries analysed by UNICEF, 63 are on track to meet the MDG1 target based on the proportion of children underweight. Three years ago, only 46 were on track, which holds some promise of improvements for certain countries. Of the 20 countries classified as not making any progress at all towards MDG1, most are in Africa.

It is important to recognize that within regions, just as within countries, great disparities exist in levels of undernutrition. Globally, among the highest levels of children stunted and underweight can be found in Burundi, East Timor (Timor-Leste), Madagascar and Yemen. In the Americas, Belize, Guyana and Panama are off track in meeting MDG1. In sub-Saharan Africa, countries with the highest underweight prevalence are Burundi, Chad, Eritrea, Madagascar and Niger. Conversely, some countries within the region are well on track to meeting MDG1 including Angola, Botswana, Congo, Ghana, Guinea-Bissau, Mozambique, Sao Tome and Principe, and Swaziland. In Asia, Bangladesh, India and Nepal are in the top ten countries with the greatest proportion of children underweight while Cambodia, Thailand and Viet Nam are on track to meet MDG1.

Progress on the proportion of the population who are undernourished
The proportion of undernourished in developing

countries, as measured by the proportion of population below minimum level of dietary energy consumption, decreased from 20% to 17% in the 1990s (a decrease in absolute numbers of 9 million) but both the proportion and absolute numbers have reversed their trend and increased in 2008 due to the food price crisis, which has severely impacted sub-Saharan Africa and Oceania regions. Sub-Saharan Africa has the highest proportion of undernourished with 29% followed by Southern Asia including India at 22%.

Most of the hungry reside in Asia and the Pacific and sub-Saharan Africa, much like the trends for underweight prevalence. Unfortunately, poor progress on addressing hunger coupled with persistently high fertility rates and population growth means the absolute number of undernourished people has been increasing since the 1990s. With 925 million people undernourished (FAO, 2010) it will be difficult to achieve either MDG1 or the 1996 World Food Summit target of reducing the absolute number of hungry people by half to 420 million by 2015 in many parts of the world.

Addressing MDG1 as part of a larger global nutrition effort

Scaling up nutrition-specific interventions

Poor nutrition arises from complex, multiple and interrelated circumstances and determinants. The immediate causes – inadequate dietary intake, water and sanitation and related diseases, lack of necessary knowledge – directly affect the individual, with disease perpetuating nutrient loss and poor nutritional status. Even without disease burden, children with inadequate nutrient intake will not grow sufficiently and are at risk of irreversible stunting.

The global community has responded to this malnutrition crisis and the lack of progress particularly amongst lagging countries (International Bank for Reconstruction and Development, 2011) by focusing on interventions that impact 90 percent of the global burden of malnutrition. There has been a particular focus on the "window of opportunity" – the first 1 000 days of a child's life from the 9 months in utero to 2 years of age. This window is critically important because nutritional setbacks during this time can result in irreversible losses to growth and cognitive potential, and reduce educational attainment and earning potential. The Scaling Up Nutrition Framework for Action (SUN),[1] recently endorsed by over 100 global partners and policy-makers,[2] highlights the need for early childhood and maternal nutrition-specific interventions which can be grouped into those that aim to:

- promote good child feeding and hygiene practices;
- provide micronutrient supplementation for young children and their mothers;
- support the provision of micronutrients through food fortification;
- treat acutely malnourished children with therapeutic feeding.

These core interventions will be critically important in addressing MDG1 as they are interventions with sufficient evidence of impacting 90 percent of the global burden of stunting in 36 countries, many of which are in Africa. Impacting this "window of opportunity" has a direct impact by reducing death, diseases and irreversible harm to future economic productivity. These actions are not costly and offer high returns over the entire lives of children at risk – in terms of their mental development, earning power and contribution to the economies and livelihoods of their communities. These nutrition-specific interventions have been identified among five of the top ten development investments that yield the highest social and economic returns.

Ensuring agriculture is a part of the scale up process

While the underlying determinants of malnutrition have been well understood for decades, the design,

[1] Scaling Up Nutrition, available at http://www.unscn.org/en/scaling_up_nutrition_sun/sun_purpose.php

[2] 1000 days initiative, available at: http://www.thousanddays.org/

testing and scaling of more holistic multisectoral packages that combine child and maternal care and disease control with nutrition-sensitive approaches, have been limited in their development and implementation. These nutrition-sensitive approaches work across development sectors to improve nutritional outcomes by promoting agriculture and food insecurity to improve the availability, access to and consumption of nutritious foods, by improving social protection (including emergency relief) and by ensuring access to healthcare (including maternal and child healthcare, water and sanitation, immunization and family planning) (Nabarro, 2010). With the tools and knowledge that are currently at our disposal, there is a renewed global focus to include interventions that address the root causes of food and nutrition security – both under- and overnutrition – as part of a wider multisector approach, which should be inclusive of agriculture.

Redirecting the global agriculture system to ensure better nutrition is critically important as agriculture is the main supplier of the world's food. The current global agriculture system is producing enough food, in aggregate, but access to sufficient food that is affordable and nutritious has been more challenging. Agriculture systems have largely become efficient at producing a handful of staple grain crops mainly maize, rice and wheat. In developing countries and particularly those in nutrition transition, people obtain most of their energy from these staple grains along with processed oils and fats, and sugars, resulting in diets that often lack micronutrients and other necessary dietary and health components.

Agriculture systems vary across the world–from large-scale monocrop landscapes to smallholder farmers who typically live on less than 2 ha of land. Smallholder farmers often farm on marginal lands without the tools, knowledge and resources to improve production, yet in places such as Africa, 90 percent of farmers are subsistence smallholder farmers. In the developing world, the majority of smallholder farmers are net food buyers, and rural households make up a substantial majority of the world's 900 million-plus hungry (FAO, 2010). As individuals who buy more than they sell, the access to affordable, nutritious food is a critical issue.
Achieving the MDG1 hunger targets clearly involve the agriculture sector–many of the poor are farmers and herders, as well as those who are hungry. Agriculture contributes to MDG1 by increasing food availability and incomes and contributing to economic growth, and higher agricultural productivity. By combining agriculture and economic growth simultaneously, with investments in health and education, child malnutrition can be reduced from 25% to 17% globally (Rosegrant *et al.,* 2006).

Agrobiodiversity: a link to what is grown and what is consumed?

Agriculture is the bedrock of the food system and biodiversity is critically important to food and agriculture systems because it provides the variety of life (Tansey and Worsley, 1995). Biodiversity includes the variety of plants, terrestrial animals and marine and other aquatic resources (species diversity), along with the variety of genes contained in all individual organisms (genetic diversity), and the variety of habitats and biological communities (ecosystem diversity). Biodiversity is essential for humanity, providing food, fibre, fodder, fuel and medicine in addition to other ecosystem services.
FAO (2010) estimates that of a total of 300 000 plant species, 10 000 plant species have been used for human food since the origin of agriculture. Out of these, only 150–200 species have been commercially cultivated with four – rice, wheat, maize and potatoes – supplying 50 percent of the world's energy needs and 30 crops providing 90 percent of the world's calorie intake. Intensification of agricultural systems has led to a substantial reduction in the genetic diversity of domesticated plants and animals in agricultural systems. Some of these on-farm losses of crop genetic diversity have been partially offset by the maintenance of genetic diversity of

seed and animal resource banks. In addition to the extinction of species, the loss of unique populations has resulted in the erosion of genetic diversity (contained in those species and populations) (Millennium Ecosystem Assessment, 2008). Yet the implications of this loss for the biodiversity and quality of the global food supply is scarcely understood and measured from a nutrition perspective.

BOX ONE:
The Convention on Biological Diversity's Definition

Agricultural biodiversity includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agro-ecosystems: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes (CBD 2010).

Agricultural biodiversity specifically, pertains to the biological variety exhibited among crops, animals and other organisms used for food and agriculture, as well as the web of relationships that bind these forms of life at ecosystem, species and genetic levels (see Box One). It not only includes crops and livestock directly relevant to agriculture, but also many other organisms that have indirect effects on agriculture, such as soil fauna, weeds, pollinators, pests and predators. Agricultural biodiversity (or agrobiodiversity) is a fundamental feature of sustainable farming systems and encompasses many types of biological resources tied to agriculture, including (Thrupp, 2000):

- genetic resources – the essential living materials of plants and animals;
- edible plants and crops, including traditional varieties, cultivars, hybrids and other genetic material developed by breeders;
- livestock (small and large, lineal breeds or thoroughbreds) and freshwater fish;
- soil organisms vital to soil fertility, structure, quality and health;
- naturally occurring insects, bacteria and fungi that control insect pests and diseases of domesticated plants and animals;
- agroecosystem components and types (polycultural/monocultural, small-/large-scale, rainfed/irrigated etc.) indispensable for nutrient cycling, stability and productivity;
- "wild" resources (species and other elements) of natural habitats and landscapes that can provide ecosystem functions and services (for example, pest control and stability) to agriculture; and
- pollinators, especially bees, bats and butterflies.

Agricultural biodiversity is the basis of the food and nutrient value chain and its use is important for food and nutrition security as potentially:

- a safety net against hunger;
- a rich source of nutrients for improved diet diversity and quality; and
- a basis to strengthen local food systems and environmental sustainability.

This agricultural biodiversity includes species with underexploited potential for contributing to food security, health, income generation and ecosystem services. Terms such as underutilized, neglected, orphan, minor, promising, niche, local and traditional are frequently used interchangeably to describe these potentially useful species (both plant and animal) which are not mainstream, but which have at least significant local importance and considerable global potential to improve food and nutrition security. Yet, the major causes of neglect and underuse of these important crops are often related to poor economic competitiveness with commodity cereal crops, lack of improved varieties or enhanced cultivation practices, the inefficiencies in the processing and value addition, disorganized or non-existent market chains, and perception of these foods being "food of the poor" (Jaenicke *et al.,* 2009).

Interspecies and intraspecies variations of crops represent a considerable wealth of local biodiversity and could have potential for contributing to improved incomes, food security and nutrition with a better understanding of their contribution and usage. They also have considerable potential to enhance adaptation to global climate change. Some of these species are highly nutritious with other multiple uses; are strongly linked to the cultural heritage of their places of origin; are highly adapted to marginal, complex and difficult environments and have contributed significantly to diversification and resilience of agro-ecological niches; and may be collected from the wild or produced in traditional production systems with little or no external inputs (Padulosi *et al.,* 2011; Bharucha and Pretty, 2010).

One area that requires further understanding is the role of agricultural biodiversity for improving diet diversity and dietary quality. Lack of diversity has been shown to be a crucial issue particularly in the developing world, where diets consist mainly of starchy staples with less access to nutrient-rich sources of food such as animal proteins, fruits and vegetables. Diet diversity is a vital element of diet quality – the consumption of a variety of foods across and within food groups, and across different varieties of specific foods, more or less guarantees adequate intake of essential nutrients and important non-nutrient factors.

Research has demonstrated a strong association between diet diversity and diet quality, and nutritional status of children (Arimond and Ruel, 2004; Kennedy *et al.*, 2007; Sawadogo *et al.,* 2006; Rah *et al.,* 2010). It is also clear that household dietary diversity is a sound predictor of the micronutrient density of the diet, particularly for young children (Moursi *et al.,* 2008). Studies have also shown that dietary diversity is associated with food security and socio-economic status, and links between socio-economic factors and nutrition outcomes are well known (Hoddinott and Yohannes, 2002; Ruel, 2003; Arimond and Ruel, 2004; World Bank, 2006; World Bank, 2007; Thorne-Lyman *et al.,* 2010).

Agrobiodiversity as an important aspect in accomplishing MDG1

The role and value of biodiversity and ecosystem services has been recognized at the centre of international efforts to reduce poverty and promote sustainable development, through the framework of the Millennium Development Goals (Ash and Jenkins, 2007). There is also a growing realization worldwide that biodiversity is fundamental to agricultural production and food security, as well as a valuable ingredient of environmental conservation, all of which are critically important to achieving the MDG1 hunger target.

Yet predominant patterns of agricultural growth have eroded biodiversity in, for example, plant genetic resources, livestock, insects and soil organism (Thrupp, 2000). Agrobiodiversity management for food security includes crop introduction, genetic manipulation, crop breeding, genetic resources conservation, agronomy, soil management and crop protection as well as delivering appropriate technologies and knowledge to farmers. Sound agrobiodiversity management therefore provides the main building blocks for appropriate and practical sustainable intensification of agricultural production for food security.

Traditional farming methods often maximize diversity in species and can provide sustainability where economic and demographic pressures for growth are low including polycultural systems that include home gardens and agroforestry systems. Agricultural biodiversity also provides ecosystem services on farms, such as pollination, fertility and nutrient enhancement, insect and disease management, and water retention (Thrupp, 2000). The practices used for enhancing biodiversity are tied to food sovereignty and cultural diversity and local knowledge that support the livelihood of agricultural communities. In many societies, women are often knowledgeable about plant and tree species and about their uses for nutrition, healthcare, fuel and fodder (see Box Two).

BOX TWO:
Biodiverse-Sourced Local and Traditional Foods

There is no universally accepted definition of local foods or traditional foods coming from biodiverse sources. Traditional foods are defined as food from a particular culture available from local resources and culturally accepted. It includes socio-cultural meanings, acquisition and processing techniques, use, composition, and nutritional consequences for people using the food (CINE 2006).

Local and traditional foods generally refers to plants and crops, fruits, non-timber forest products, livestock, fish, hunted game, wetland species, wild or gathered foods and insects.

These components of agrobiodiversity have benefits. They contribute to productivity, resilience in farming systems, income generation, and food and livelihood security for numerous societies, and potentially, achieving the MDGs. Agricultural biodiversity is essential in augmenting the productivity and resilience of agricultural systems allowing a more stable food security for smallholder farmers (Thrupp, 2000; Jackson *et al.*, 2007; Borron, 2006). For example, agricultural biodiversity is an important factor in raising incomes, allowing farmers to sell diverse products at market, often characterized by positive value chain elements (Thrupp, 2000; Baumgärtner, 2010). Although rising incomes do not correlate directly with better nutrition, if they are coupled with the correct information dissemination and educations efforts, they may lead to extra money being spent on better, more nutritious foods (Blaylock *et al.*,1999). The role of agricultural biodiversity is also important in mitigating the need of pesticides as these have been shown to have multiple adverse effects on human health and nutrition (EPA, 2011).

For many populations, biodiversity overall, particularly plant species such as lesser-known grains and legumes, leafy green vegetables, tubers, crop wild relatives and forest fruits, play an important role in traditional diets and in some cases, income generation. As shown in Box Three, more research and understanding of the value of traditional foods is being developed. Nutritionists now increasingly insist on the need for more diverse agroecosystems, in order to ensure a more diversified nutrient output of the farming systems. However, little is known about most traditional plants' nutritional value, usage and consumption patterns and their subsequent impact on human health, chronic undernutrition and over-nutrition and non-communicable disease risk.

Thoughts on sustainability beyond the MDGs

It is important that countries and the international community start thinking in a different way about agriculture, nutrition and health. It is no longer possible to see agriculture and nutrition as a simple matter of inputs and outputs which work in a semi-mechanical and extremely simplified way. It is essential that we take into consideration complex food system-based approaches in order to understand processes which are intrinsically affected by the complexity of life and living beings (Burchi and Fanzo, 2010). In order to produce healthy, nutritious foods we must encourage a healthy, sustainable model of agriculture based on healthy dynamic soils, the variety and rotation of different crops, on fair and inclusive market outcomes. In the same way, if we hope to combat malnutrition we must concentrate on more than just providing enough "fuel" to the body but rather understand that nutrition is closely interlinked with a myriad of factors such as agriculture but also customs, culture, preferences, tastes, health, sanitation, livelihood models, economics, history and anthropology.

In order to achieve MDG1, we must promote efforts aimed at improving the whole food system, starting from agriculture, passing through nutrition and health and terminating with what Amartya Sen defined as human "capabilities" (Sen, 1985). It is only inside a system which demonstrates biodiverse and biodynamic agriculture not only as a source of food but also as an economic livelihood, a source of

BOX THREE: Traditional African green leafy vegetables find their way to formal markets

African Leafy Vegetables (ALVs) are important sources of essential macro and micro-nutrients. In addition they offer a source of livelihood when marketed as well as contribute to crop biodiversity. Sub-Saharan Africa contains a large variety of nutritious, leafy vegetables—an estimated 800–1 000 species. In Kenya, where approximately 210 species are available, only about 10 find their way to markets (mainly African nightshade, leafy amaranth, cowpeas and spider-plant). Bioversity works with resource-poor vegetable farmers on the outskirts of Nairobi, in peri-urban areas. Together they have inventoried leafy vegetable species and identified the key issues hindering their cultivation, conservation, and marketing. Other activities include nutritional and agronomic studies, distribution of seeds to farmers, and dissemination of local recipes featuring leafy vegetables to stimulate demand. With support and training from the project, farmers on the outskirts of Nairobi began growing leafy vegetables.
Results from a study commissioned by the Global Facilitation Unit for Underutilized Species (GFU) in 2006 show that over the last one decade, the growth of the ALV market within Nairobi has been tremendous. In Nairobi the market gross value has increased by about 213% between the period 2001 and 2006. The campaign for traditional vegetables between 1997 and 2007 brought notable positive changes in growing, consuming, marketing and nutritional awareness of ALVs. The growth of this market has been greatly influenced by an increased consumer demand that has been caused by a number of factors. These include promotional strategies of local NGOs and international organizations, increased health awareness and consciousness of Nairobi dwellers, effects of HIV/AIDs, and improved ALV presentation in supermarkets and upmarket groceries. On the other hand supply has been enhanced by promotion of production in peri-urban and upcountry key production areas by international organizations and local NGOs, provision of external marketing support by NGOs, farmers' capacity for self-organization, and improvement of telecommunication technology (Gotor and Irungu, 2010).

a societal framework, and a source of customs and traditions, that we can attempt to ensure that nutrition is an outcome and benefits child and maternal health. In the same way, we must understand how water sanitation, health services, and economic pressures affect child nutrition and how these can be linked back to agriculture, rural society and markets.

It will be critically important to generate a better understanding of the links among agricultural biodiversity, diet quality, and nutrition and health, and the overall role of nutrition within agricultural food systems. Large-scale evidence is needed of the impact of agricultural biodiversity on health in diverse developing world settings. The feasibility of a long-term approach towards diversification of nutrient-dense crops and their impact on addressing the significant deficits in micronutrients and other important health factors amongst global communities is also under-researched. Biodiversity has been shown to be critically important in food security, sustainable agriculture approaches – both of which are essential in translated accomplishment towards reaching MDG1 beyond its life of 2015.

Accelerating progress towards the MDG1 hunger targets is less about the development of novel innovations and new technologies and more about putting what is already known into practice, with some efforts towards sustainable agriculture approaches that include the conservation and usage of agricultural biodiversity. Success will hinge on linking clear policies with effective delivery systems for an evidence-based and contextually relevant package of interventions that can rapidly be taken to scale. Persistent hunger and undernutrition remain an inexcusable unfinished agenda and successfully closing the few remaining gaps is a pre-condition for wider global progress towards achieving the MDGs.

References

Arimond, M., and Ruel, MT. (2004) Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. Journal of Nutrition 134 (10): 2579–2585.

Ash, N. and Jenkins M. (2007) United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). Biodiversity and Poverty Reduction: The importance of biodiversity for ecosystem services. Cambridge MA.

Baumgärtner S., Quaas M. (2010) Managing increasing environmental risks through agrobiodiversity and agrienvironmental policies. Agricultural Economics Volume 41, Issue 5, Pages 483-495

Bharucha and Pretty (2010) The roles and values of wild foods in agricultural systems. Philosophical Transactions of the Royal Society. 365: 2913-2926.

Blaylock J., Smallwood D., Kassel K. (1999) Economics, Food Choices and Nutrition. Food Policy Volume 24, Issues 2-3, May 1999, Pages 269-286.

Borron S. (2006) Building Resilience for an Unpredictable Future. Food and Agriculture Organization (FAO).

Burchi F. & Fanzo J. (2010). "The Role of Food and Nutrition System Approaches in Tackling Hidden Hunger" Int. J. Environ. Res. Public Health 2011, 8, 358-373.

CINE (2006) Documenting traditional food systems of indigenous peoples: International Case Studies. CINE, IDRC and FAO. Rockefeller Foundation.

Convention on Biological Diversity (2010) Fact Sheet. http://www.cbd.int/iyb/doc/prints/factsheets/iyb-cbd-factsheet-agriculture-en.pdf Accessed December 21, 2010.

Food and Agriculture Organization of the United Nations (FAO) (2010) The Commission on Genetic Resources for Food and Agriculture (CGRFA) Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture (PGRFA). Rome, Italy.

Gotor, E., & Irungu, C. (2010). The impact of Bioversity International's African Leafy Vegetables programme in Kenya Impact Assessment and Project Appraisal, 28 (1), 41-55.

Hoddinott J. and Y. Yohannes. (2002) "Dietary diversity as a food security indicator." (Discussion paper 136) International Food Policy Research Institute (IFPRI). Washington, D.C.

International Bank for Reconstruction and Development (2011) Improving the Odds of Achieving the MDGs: Global Monitoring Report 2011. World Bank. Washington DC.

Jaenicke J. Ganry I. Hoeschle-Zeledon and R. Kahane Eds (2009). Proceedings of the International Symposium on Underutilized Plants for Food Security, Nutrition, Income and Sustainable Development. Acta Hort. ISHS. 806 (Vol I-II) 739 pp.

Jackson L.E., Pascual U., Hodgkin T. (2007) Utilizing and conserving agrobiodiversity in agricultural landscapes. Agriculture, Ecosystems and Environment 121 (2007) 196–210.

Kennedy G.L., Pedro M.R., Seghieri C., Nantel G., Brouwer I. (2007) Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children. J Nutr 137, 472–477.

Millennium Ecosystem Assessment (2008) Ecosystems and Human Well-Being: Biodiversity Synthesis. World Resources Institute, Washington DC.

Moursi M., Arimond M. and Deweg KG. (2008) Dietary Diversity Is a Good Predictor of the Micronutrient Density of the Diet of 6- to 23-Month-Old Children in Madagascar. J. Nutr. 138: 2448-2453.

Nabarro D. (2010). Introducing the policy brief "Scaling up nutrition: a framework for action". Special Representative of the UN Secretary General for Food Security and Nutrition. http://siteresources.worldbank.org/NUTRITION/Resources/042410DavidNabarroIntroducingtheSUN.pdf

Padulosi S. *et al* (2011) Underutilized species and climate change – current status and outlook. In: Crop Adaptation to Climate Change. Wiley-Blackwell, US (In press).

Popkin B. (2008) The World Is Fat: The Fads, Trends, Policies, and Products That Are Fattening the Human Race. Penguin.

Rah, JH Akhter, N, Semba, RD, de Pee, S, Bloem, MW, Campbell, AA, Moench-Pfanner, R Sun, K, Badham, J and Kraemer K. (2010) Low dietary diversity is a predictor of child stunting in rural Bangladesh. European Journal of Clinical Nutrition 64, 1393–1398.

Rosegrant, Mark W., Ringler, Claudia, Benson, Todd, Diao, Xinshen, Resnick, Danielle, Thurlow, James, Torero, Maximo, Orden, David (2006) Agriculture and achieving the Millennium Development Goals. IFPRI. Washington DC.

Ruel, M.T. (2003) Operationalizing dietary diversity: a review of measurement issues and research priorities. Journal of Nutrition 133 (11 Suppl 2): 3911S-26S.

Sawadogo PS., Martin-Prevel Y., Savy M., Kameli Y., Traissac P., Traore AS. et al. (2006) An infant and child feeding index is associated with the nutritional status of 6- to 23-month-old children in rural Burkina Faso. J Nutr 136, 656–663.

Sen, A. (1985) Commodities and Capabilities, Oxford: Elsevier Science Publishers.

Tansey G. and Worsley. T (1995) The Food System. Earthscan, London.

Thorne-Lyman AL., Valpiani N., Sun K., Semba RD., Klotz CL., Kraemer K. et al (2010) Household dietary diversity and food expenditures are closely linked in rural Bangladesh, increasing the risk of malnutrition due to the financial crisis. J Nutr 140, 182S–188S.

Thrupp LA. (2000). Linking Agricultural Biodiversity and Food Security: The Valuable Role of Sustainable Agriculture. Royal Institute of International Affairs Vol. 76, No. 2, Special Biodiversity Issue pp. 265-281.

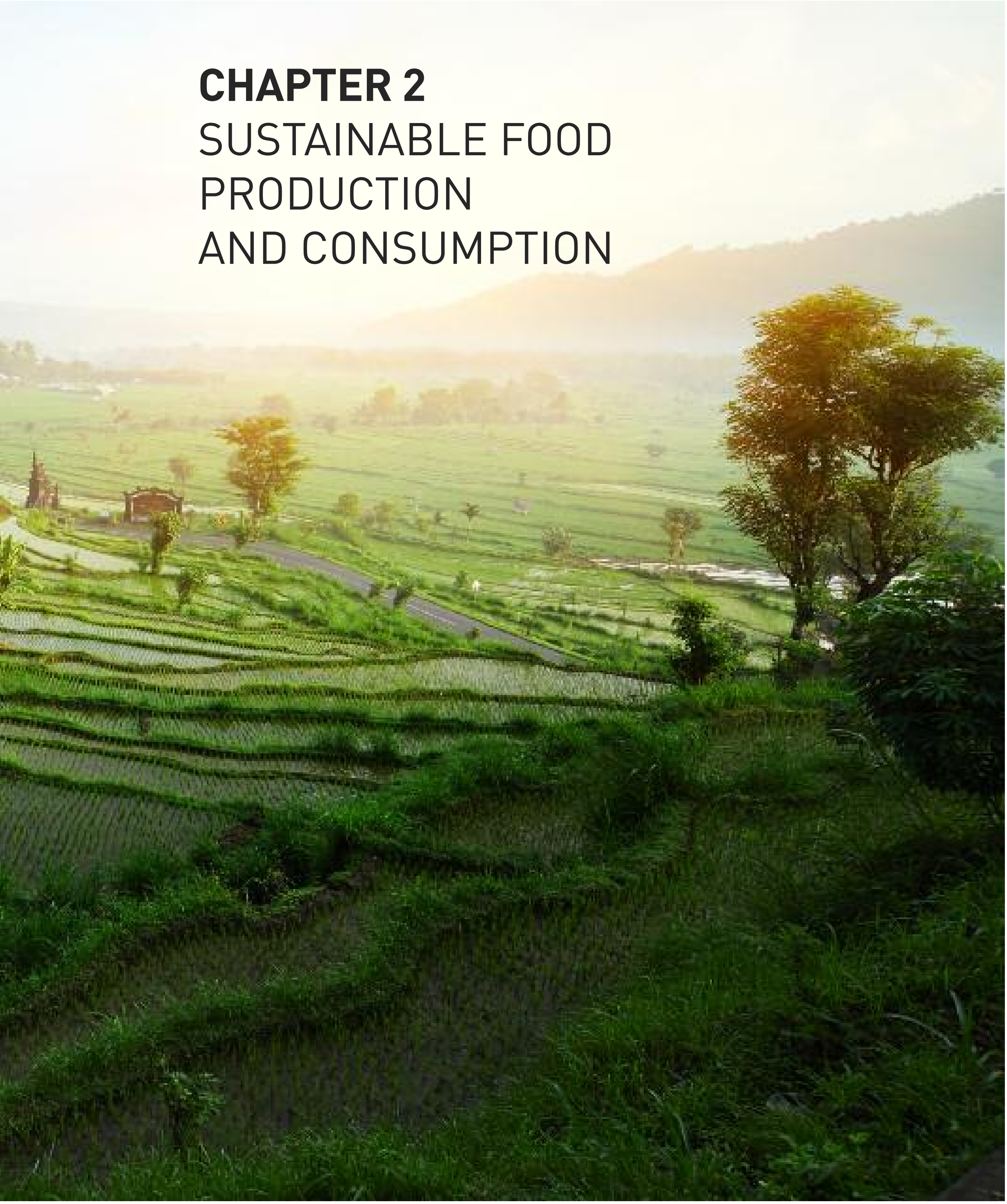
US Environmetal Protection Agency (2011). Pesticides and Food – Health Problems Pesticides May Cause.

World Bank. (2006) Repositioning nutrition as central for development. World Bank. Washington, DC.

World Bank. (2007) From agriculture to nutrition: Pathways synergies and outcomes. World Bank. Washington, DC.

World Health Organization (2006) WHO Fact sheet No 311 September 2006: Obesity and overweight. World Health Organization. Geneva.

CHAPTER 2
SUSTAINABLE FOOD PRODUCTION AND CONSUMPTION



DYNAMIC CONSERVATION OF GLOBALLY IMPORTANT AGRICULTURAL HERITAGE SYSTEMS: FOR A SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT

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Abstract
The story of world agriculture is closely interwoven with that of the evolution of human civilization and of its diverse cultures and communities across the globe. In many developing countries, agricultural and rural life to this day is considerably influenced by the society's ancient cultural traditions and local community institutions and values, which are mostly conditioned by natural endowments, wealth and breadth of accumulated knowledge and experience in the management and use of natural resources. The Globally Important Agricultural Heritage Systems are dispersed over many countries and regions, and represent a microcosm of the larger rural world of land-use systems, livestock, pastures, grasslands, forestry and fisheries. They reflect the value of the diversity of agricultural systems adapted to different environments and tell a fascinating story of man's ability and cultural ingenuity to adjust and adapt to the vagaries of a changing physical and material environment, from generation to generation and leave indelible imprints of an abiding commitment to nature conservation and respect for their agricultural patrimony. These agricultural heritage systems have a contemporary relevance, among others, for providing sustainable diets for the rural poor, food sovereignty, livelihood security and sustainable development.

1. Introduction

Throughout centuries, human communities, generations of farmers, herders and forest people have developed complex, diverse and locally adapted agricultural and forestry systems. These systems have been managed with time-tested ingenious combinations of techniques and practices that have usually led to community food security and the conservation of natural resources and biodiversity. These microcosms of agricultural heritage can still be found throughout the world covering about 5 million ha which provide a series of cultural and ecological services to humankind such as the preservation of traditional forms of knowledge systems, traditional crops and animal varieties and autochthonous forms of sociocultural organizations. These agricultural heritage systems have resulted not only in outstanding landscapes of aesthetic beauty, maintenance of globally significant agricultural biodiversity, resilient ecosystems and valuable cultural inheritance, but above all, in the sustained provision of multiple goods and services, food and livelihood security for millions of poor and small farmers. Their agricultural biodiversity is maintained and dynamically conserved by rural farming communities through localized, traditional ecological agricultural practices/knowledge systems. However, many of these globally important biological diversity and ecological friendly agricultural systems and their goods and services are threatened by several factors such as lack of or low priorities for family farming systems, lack of access to market, displacement of local agricultural practices, lack of social organization and financial-institutional support that underpin management of these systems. Thus, the desired progress towards a sustained economic development process is compromised and thereby resulting in disparities between and among communities.

2. What are GIAHS?

The Food and Agriculture Organization (FAO) of the United Nations defines Globally Important Agricultural Heritage Systems (GIAHS) as "remarkable land use systems and landscapes which are rich in globally significant biological diversity evolving from the co-adaptation of a community with its environment and its needs and aspirations for sustainable development" (FAO, 2002). GIAHS are classified and typified based on its ingenuity of management systems, high levels of agricultural biodiversity and associated biodiversity, local food security, biophysical, economic and sociocultural resources that have evolved under specific ecological and sociocultural constraints and opportunities. The examples of such agricultural heritage systems are in the hundreds and are home to thousands of ethnic groups, indigenous communities and local populations with a myriad of cultures, languages and social organizations (Koohafkan and Altieri, 2010). Examples of GIAHS could fall into:

I. *Mountain rice terrace agro-ecosystems.* These are outstanding mountain rice terrace systems with integrated forest use and/or combined agroforestry systems

II. *Multiple cropping/polyculture farming systems.* These are remarkable combinations and/or plantings of numerous crop varieties with or without integration of agroforestry. They are characterized by ingenious microclimate regulation, soil and water management schemes, and adaptive use of crops to deal with climate variability.

III. *Understory farming systems.* These are agricultural systems using combined or integrated forestry, orchard or other crop systems with both overstory canopy and understory environments. Farmers use understory crops to provide earlier returns, diversify crops/products and/or make efficient use of land and labour.

IV. *Nomadic and semi-nomadic pastoral systems.* These are the rangeland/pastoral systems based on adaptive use of pasture, rangeland, water, salt and forest resources, through mobility and variations in herd composition in harsh non-equilibrium environments with high animal genetic diversity and outstanding cultural landscapes.

V. *Ancient irrigation, soil and water management systems.* These are the ingenious and finely tuned irrigation, soil and water management systems most common in drylands, with a high diversity of crops and animals best adapted to such environments.

VI. *Complex multilayered home gardens*. These agricultural systems feature complex multilayered home gardens with wild and domesticated trees, shrubs and plants for multiple foods, medicines, ornamentals and other materials, possibly with integrated agroforestry, swidden fields, hunting-gathering or livestock, and home garden systems.

VII. *Below sea level systems.* These agricultural systems feature soil and water management techniques for creating arable land through draining delta swamps. The systems function in a context of rising sea and river levels while continuously raising land levels, thereby providing a multi-functional use of land (for agriculture, recreation and tourism, nature conservation, culture conservation and urbanization).

VIII. *Tribal agricultural heritage systems.* These systems feature various tribal agricultural practices and techniques of managing soil, water and crop cultivars in sloping lands from upper to lower valleys using mixed and/or a combination of cropping systems and integrating indigenous knowledge systems.

IX. *High-value crop and spice systems*. These systems feature management practices of ancient fields and high-value crops and spices, devoted uniquely to specific crops or with crop rotation techniques and harvesting techniques that require acquired handling skills and extraordinary finesse.

X. *Hunting-gathering systems.* These systems feature unique agricultural practices such as harvesting of wild rice, honey gathering in the forest, and other similar unique practices.

3. Dynamic conservation of agricultural heritage systems

In the past decades, conventional agricultural policies have assimilated the food security and agricultural development largely through increased food production by energy-intensive modern agriculture, which is a fossil fuel based industry and its development is tightly linked to energy factors, trade and globalization. While the successes in agriculture production over the last decades are viewed as a major landmark, the inequitable benefits and negative impacts of such policies on natural resources are becoming more evident. Undoubtedly, the acceleration of environmental degradation and climate change also has had adverse impacts on agricultural productivity and food security. Such an adverse impact on agricultural productivity is more and more becoming obvious in the more fragile tropical environmental situations of the developing world. The environmental degradation and linked declining crop productivity that the two large Asian countries, namely, India and China are facing today and the emerging concerns for sustainable agriculture (Ramakrishnan, 2008 unpublished) are indicative of the emerging global food security concerns, and equitable distribution of what is available so that all sections of the society are able to benefit. This is the context in which the still existing traditional agricultural systems conserved by many traditional farming societies (those living close to nature and natural resources) largely confined to the developing tropics have an important role to play. Rather than being seen as an industrial activity as modern agriculture tends to be, traditional agricultural systems are organized and managed through highly adapted social and cultural practices and institutions wherein the concerns are for food security linked with equitable sharing of what is available. Equity is ensured through locally relevant technologies that are cheap since they are based on effective utilization of the continually evolving traditional wisdom linked with locally available natural resources and their effective management that is community participatory. Indeed, traditional agricultural and ecological knowledge and the derived traditional technologies that societies have developed through an experiential process form the basis for addressing productivity consideration with equitability concerns in mind. In this process they manipulate natural and human-managed biodiversity in a variety of different ways towards sustainable production with concerns also for coping with the environmental uncertainties that they have to face from time to time. FAO's GIAHS initiative is seeking to identify outstanding traditional agricultural systems and support their dynamic conservation as well as sustainable evolution. GIAHS can be viewed as benchmark systems for international and national strategies for sustainable agricultural development and addressing the rising demand to meet food and livelihood needs of poor and remote populations. Dynamic conservation implies what the traditional farmers have always practised, namely, adaptive management of their systems under changing environmental considerations, both in time and space. GIAHS have always faced many challenges in adapting to rapid environmental and socio-economic changes in the context of weak agricultural and environmental policies, climate variability and fluctuating economic and cultural pressures (Altieri and Koohafkan, 2008). There is no doubt, these threats vary from one country to another, but there are common denominators that are rapidly emerging in the global scene: (a) "global change" in an ecological sense, involving land use land cover changes, biodiversity depletion, biological invasion and of course the emerging climate change and linked global warming; and (b) economic "globalization" that would accentuate the problem of landscape homogenization arising from the implication that globalization implies, namely, intensive management of vast areas of the land through monocropping practices. These global threats emphasize the need to ensure dynamic conservation of selected systems which could then form the basis for conserving both agricultural and linked natural biodiversity, at the same time using such systems as learning grounds towards addressing the diverse viewpoints of "sustainable agriculture". Once lost, the unique agricultural legacy and the associated eco-agricultural heritage will also be lost forever. Hence, there is a need to carefully identify agricultural heritage systems wherever they exist, with a view to dynamically conserve them and thereby promote the basic goods and services humanity needs today and for the future generations. The GIAHS initiative is conceived as being inclusive and forward looking with agricultural patrimony serving as models for agricultural development in similar environments, i.e. uplands, drylands, wetlands management etc. based on the experience and learning from the pilot projects. The GIAHS initiative is not just a collection of local projects; it has a global focus within the framework of policies promoting local food security through sustainable systems. Thus, GIAHS, while starting initially on some pilot countries in the developing and developing world, is looking forward to expand with a more inclusive international coverage and recognition of such evolving, living agricultural systems as an important global initiative to promote sustainable development, enhance food security and promote conservation of biodiversity of nutritional importance for the local communities. Figure 1 shows the unique features and principles of GIAHS derived from such sites that may be replicated in other farming systems to achieve sustainability and resiliency.

4. GIAHS pilot systems around the world

The GIAHS initiative has selected pilot systems located in several countries of the developing world. The values of such systems not only reside in the

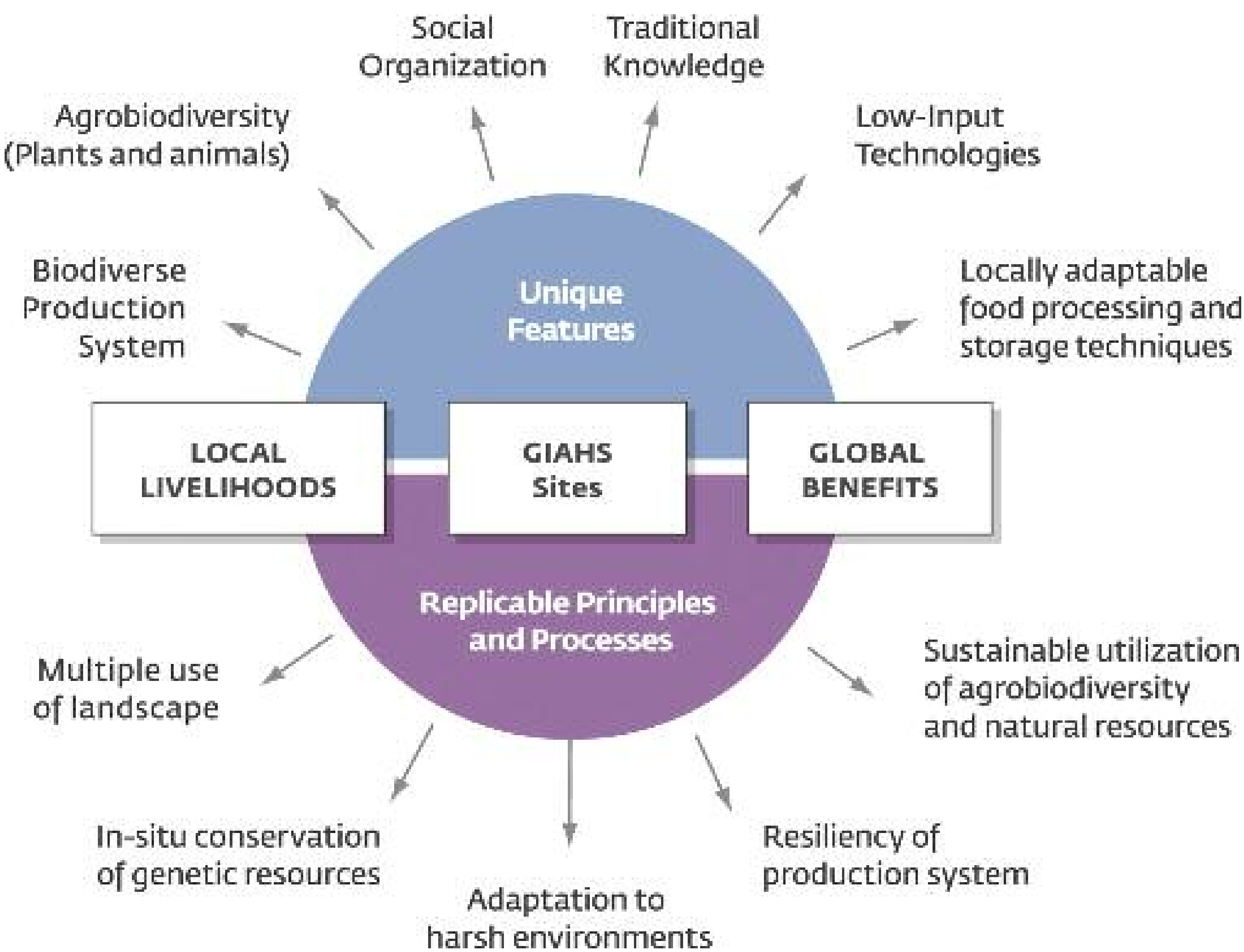

Figure 1. The unique features and principles of GIAHS sites that may be replicated in other farming systems to achieve sustainability and resiliency.

fact that they offer outstanding aesthetic beauty, are key in the maintenance of globally significant agricultural biodiversity, and include resilient ecosystems that harbour valuable cultural inheritance, but also have sustainably provisioned multiple goods and services, food and livelihood security for millions of poor and small farmers, local community members and indigenous peoples, well beyond their borders. Despite the fact that in most parts of the world, modernity has been characterized by a process of cultural and economic homogenization, in many rural areas specific cultural groups remain linked to a given geographical and social context in which particular forms of traditional agriculture and gastronomic traditions thrive. It is precisely this persistence that makes for the selection of these areas and their rural communities a GIAHS site. The dynamic conservation of such sites and their cultural identity is the basis of a strategy for territorial development and sociocultural revival. Overcoming poverty, food insecurity is not equivalent to resignation to loss of the cultural richness of rural communities. On the contrary, the foundation of regional development should be the existing natural and agricultural biodiversity and the sociocultural context that nurtures it. Brief descriptions of some of the pilot Agricultural Heritage Systems and their features are presented in Table 1.


Rice Fish culture in China

Table 1. List of pilot systems for dynamic conservation of Globally Important Agricultural Heritage Systems.

Country/Systems	Main characteristics and important source of food security and nutrition diets
Chile/Chiloé Agriculture System	The Archipelago of Chiloé, a group of islands in southern Chile, is a land rich in mythology with native forms of agriculture practised for hundreds of years based on the cultivation of numerous local varieties of potatoes. Traditionally the indigenous communities and farmers of Chiloé cultivated about 800–1 000 native varieties of potatoes. The varieties that still exist at present are the result of a long domestication through selection and conservation processes of ancient Chilotes.
Peru/Andean Agriculture System (The Cuzco-Puno Corridor)	Andean people have domesticated a suite of crops and animals. Of particular importance are the numerous tubers, of which the potato is the most prominent. Generations of Aymara and Quechua have domesticated several hundred varieties in the valleys of Cusco and Puno, of which more than 400 varieties are still grown today. The maintenance of this wide genetic base is adaptive since it reduces the threat of crop loss due to pests and pathogens specific to particular strains of the crop. Other tubers grown include oca, mashua, ullucu, arracacha, maca, achira and yacón.
Philippines/Ifugao Rice Terraces	The ancient Ifugao Rice Terraces (IRT) are the country's only highland mountain rice ecosystem (about 68 000 ha) featuring the Ifugao ingenuities, which has created a remarkable agricultural organic paddy farming system that has retained its viability over 2 000 years. IRT paddy farming favours planting traditional rice varieties of high quality for food and rice wine production.
China/Rice-Fish Culture (Qingtian County)	In Asia fish farming in wet rice fields has a long history. Over time an ecological symbiosis has emerged in these traditional rice-fish agricultural systems. Fish provide fertilizer to rice, regulate microclimatic conditions, soften the soil, displace water and eat larvae and weeds in the flooded fields; rice provides shade and food for fish. Furthermore, multiple products and ecological services from the rice ecosystems benefit local farmers and the environment. Fish and rice provide high quality nutrients and an enhanced living standard for farmers.
China/Hani Rice Terraces	Hani Rice Terraces are located in the southeast part of the Yunnan Province. Hani Rice Terraces are rich in agricultural biodiversity and associated biodiversity. Of the original 195 local rice varieties, today there are still about 48 varieties. To conserve rice diversity, Hani people are exchanging seed varieties with surrounding villages
China/Wannian Traditional Rice Culture	Wannian traditional rice was formerly called "Wuyuanzao" and is now commonly known as "Manggu", cultivated in Heqiao Village since the North and South Dynasty. Wannian varieties are unique traditional rice varieties as they only thrive in Heqiao Village. This traditional rice is of high nutritional value as it contains more protein than ordinary hybrid rice and is rich in micronutrients and vitamins. Rice culture is intimately related to local people's daily life, expressed in the cultural diversity of their customs, food and language.
Tunisia/Gafsa Oases	The Gafsa Oases in Tunisia covers an area approximately 36 000 ha. It has numerous production systems, which are very diverse, unique, intensively cultivated but very productive. These agro-ecological production systems allow conservation and maintenance of biological diversity of local and global significance. Over a thousand years, the hundreds of palm and fruit tree varieties, vegetables and forage crops have provided the food systems and food requirements of the communities living in and around the Tunisian oases and of the populations of the Maghreb Region.
Morocco/Oases in the High Atlas Mountains	In this mountain oasis, they developed their own ingenious and practical solutions for managing natural resources which are still in place today. Their reliance on local biodiversity for subsistence and health (aromatic and medicinal plant species) has promoted the conservation and maintenance of diverse plant genetic resources, in a complex and stratified landscape in the green pockets of the oases and through associated knowledge and practices.
Tanzania/Shimbwe Juu Kihamba Agroforestry	The Chagga tribe on Mt. Kilimanjaro had created a multitier agroforestry system some 800 years ago. It is locally known as Kihamba and covers some 120 000 ha. This agroforestry system had provided food security and livelihoods for the highest population densities known in Africa without compromising sustainability. During colonial times

	coffee was adopted by farmers which allowed its adaptation to a more cash crop oriented society. The Kihamba cultivate combined perennial (indigenous trees with vines, banana, coffee, shrubs) and annual crops.
Kenya/Maasai Pastoral System	For more than a thousand years, the Maasai in southern Kenya and northern Tanzania have developed and maintained a highly flexible and sustainable mobile livestock-keeping system, moving herds and people in harmony with nature's patterns. Their customary institutions for collectively managing livestock, pastures, water, forest and other natural resources, combined with vast traditional knowledge and strong cultural traditions, treating nature with respect.
Algeria/El Oued, Souf Ghout System	In an arid region such as El Oued, where rainfall is almost absent, the groundwater reserves provide essential support to all human life, animal and plant. To overcome the lack of surface water, the farmers irrigate their palms plantation by groundwater. The method of irrigating groves of El Oued is quite original: it is to get the roots of the palm into the groundwater and will be continuously in contact with water. The population cultivates their palms in the crater called Ghout, to reduce the depth between the ground and the roots of the palm.
Japan/Sado Island	Sado is characterized by a variety of landforms and altitudes, which have been ingeniously harnessed to create the satoyama landscape, a dynamic mosaic of various socio-ecological systems comprising secondary woodlands, plantations, grasslands, paddy fields, wetlands, irrigation ponds and canals. Within their complex ecosystem, the satoyama and the satoumi landscapes in Sado Island harbour a variety of agricultural biodiversity, such as rice, beans, vegetables, potatoes, soba, fruit, grown in paddy fields and other fields, livestock, wild plants and mushrooms in forests, and seafood in the coastal areas. Rice, beef and persimmon from the Sado are among the best in Japan.
Japan/Noto Peninsula	The peninsula is a microcosm of traditional rural Japan where agricultural systems are integrally linked to mountains and forest activities upstream and coastal marine activities downstream. Holistic approaches to integrated human activities of fishing, farming and forestry have traditionally been practised and continue to co-exist. Hilly terrain interspersed with wide valleys and fields forming a green corridor surrounded by volcanic rock coastline typify the peninsular landscape. Noto Peninsula has been gaining recognition both locally and regionally for its traditional vegetables and rice varieties. Over 20 varieties of indigenous aburana (rape varieties of cruciferous vegetables) families grow and are consumed by a majority of satoyama satoumi households in the peninsula.

(For more details, please refer to www.fao.org/nr/giahs)

Ecological farming, Chiloe

Native potatoes, Peru

5. Examples of dynamic conservation: The case of the rice-fish culture in China

For more than 5 years of implementation, the GIAHS site in China has started Longxian village, a rice-fish culture system. Fish provide nutrition and fertilizer to rice, regulate microclimatic conditions and eat larvae and weeds in the flooded fields, reducing the cost of labour needed for fertilizer and insect control. The rice-fish culture self-sufficiency production provides favourable eco-environmental conditions that are also beneficial to conservation of other crop species for home gardens of importance to local food nutrition and diets, i.e. lotus roots, beans, taro, eggplant, Chinese plums, mulberry and forest tree species of ethnobotanical and medicinal uses. However, population emigration and modern technologies to intensify production are threatening the rice-fish culture system in the village. Through the GIAHS initiative, rice-fish practices in China have made a comeback and given hope to small farmers. FAO assisted the national and local institutions to develop and implement an action plan and a supportive institutional framework. The local government of Qingtian has internalized the GIAHS concept and has taken steps forward to promote the conservation of their agricultural heritage. They have issued a temporary legislation to promote rice-fish conservation and development in 2010. The Qingtian Bureau of Agriculture, Environmental Protection, Culture and Tourism has also made great effort to support and encourage local farmers to join the conservation programme. Since then, Longxian village has become popular among tourists (local and foreign) and the number of visitors has increased more than threefold. GIAHS have created awareness of conservation in Longxian village in China, because it has helped stakeholders become aware that multiple goods and services exist in traditional agricultural systems. The system provides economic and nutritional values (healthy food, nutritious rice and fish products), social values (labour occupation), ecological (rich agricultural biodiversity, clean and healthy farms and environment), and cultural and ecotourism values for humanity. Dynamic conservation of GIAHS has offered many opportunities for socio-economic and research development, such as: rice-fish system for research and education, fish and rice delicacies, aesthetic landscape, old mountain village, and folk-custom culture.

6. Summary and way forward for sustainable agriculture and rural development

Globally Important Agricultural Heritage Systems are living, evolving systems of human communities in an intricate relationship with their territory, cultural or agricultural landscapes or biophysical and wider social environment. The humans and their way of life have continually adapted to the potentials and constraints of the social-ecological environments, and shaped the landscapes into remarkable and aesthetic beauty, accumulated wealth of knowledge systems and culture, local food systems and diets, and in the perpetuation of the biological diversity of global significance. Many GIAHS and their unique elements are under threats and facing disappearance due to the penetration of global commodity driven markets that often create situations in which local producers or communities in GIAHS have to compete with agricultural produce from intensive and often subsidized agriculture in other areas of the world. All of these threats and issues pose the risk of loss of unique and globally significant agricultural biodiversity and associated knowledge, aesthetic beauty, human culture, and thereby threatening the livelihood security and food sovereignty of many rural, traditional and family farming communities. Moreover, what is not being realized is that, once these GIAHS unique key elements are lost, the agricultural legacy and associated social-ecological and cultural, local and global benefits will also be lost forever. Therefore, policies are needed to support dynamic conservation of agricultural heritage and safeguard it from the negative external drivers of change. It is likewise important to protect the natural and cultural assets of

GIAHS sites from industrial development, which often extract labour and cause market distortion as well. Special attention should be given when introducing modern agricultural varieties and inputs to avoid upsetting the balance of traditional agro-ecosystems. Success in sustainable agriculture development will depend on the use of a variety of agro-ecological improvements in addition to farm diversification, favouring better use of local resources; emphasizing human capital enhancement; empowerment of rural communities and family farmers through training and participatory methods; as well as higher access to equitable markets, credit and income-generating activities, and all should be supported by conducive policies.

References

Altieri, M. and Koohafkan, P. 2008. Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities. Environment & Development. Series 6. Third World Network (TWN), Penang, Malaysia. 63 pp.

FAO (2002). Conservation and adaptive management of globally important agricultural heritage systems (GIAHS), Global Environment Facility, Project Concept Note.

Koohafkan, P. and Altieri, M. 2010. Globally Important Agricultural Heritage Systems: a legacy for the future.

Globally Important Agricultural Heritage System (GIAHS) webpage www.fao.org/nr/giahs

Native dates, Oases, Tunisia

Rice-fish culture, China

SUSTAINABLE CROP PRODUCTION INTENSIFICATION

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Abstract

The green revolution led to enormous gains in food production and improved world food security. In many countries, however, intensive crop production has had negative impacts on production, ecosystems and the larger environment putting future productivity at risk. In order to meet the projected demands of a growing population expected to exceed 9 billion by 2050, farmers in the developing world must double food production, a challenge complicated by the effects of climate change and growing competition for land, water and energy. The paper outlines a new paradigm, Sustainable Crop Production Intensification (SCPI), which aims to produce more from the same area of land, through increasing efficiency and reducing waste, while conserving resources, reducing negative impacts on the environment and enhancing the provision of ecosystem services. The paper highlights the underlying principles and outlines some of the key management practices and technologies required to implement SCPI, recognizing that the appropriate combination will depend on local needs and conditions, and on the development of supportive policies and institutions.

1. The challenge

The world's population is expected to grow to over 9 billion people by 2050; there will be a need to raise food production by some 70 percent globally and by almost 100 percent in developing countries. In many developing countries there is little or no room for expansion of arable land. Virtually no spare land is available in South Asia and the Near East/North Africa. Where land is available, in sub-Saharan Africa and Latin America, more than 70 percent suffers from soil and terrain constraints. An estimated 80 percent of the required food production increases will thus need to come from land that is already under cultivation at a time when annual growth in crop productivity is decreasing from a rate of around 3 to 5 percent a year in the 1960s to a projected 1 percent in 2050. Increases in agricultural production will therefore have to come in the form of yield increases and higher cropping intensities.

This increase must be achieved against a challenging backdrop including the decreasing availability of and competition for water, resource degradation (e.g. poor soil fertility), energy scarcity (resulting in higher costs for input production and transport) as well as climate change where alterations in temperature, precipitation and pest incidence will affect farmers' choice of crops to grow and when, as well as their potential yields. Changing dietary and nutritional needs and requirements as a result of urbanization also present a challenge. By 2050, some 70 percent of the world population will be urban dwellers as compared to 50 percent today. If such trends continue, urbanization and income growth in developing countries will lead to higher consumption of animal products which will further drive increased demand for cereals to feed livestock (FAO, 2011).

2. The green revolution

The green revolution of the 1960s and 1970s was a qualified success. The production model, which initially focused on the introduction of higher yielding varieties of rice, wheat and maize relied upon and promoted homogeneity: genetically uniform varieties grown with high levels of complementary inputs such as irrigation, fertilizers and pesticides. Fertilizer use tended to replace soil quality management while herbicides provided an alternative to crop rotation as a means of controlling weeds (FAO, 2011).

The green revolution is credited, especially in Asia, as having jump-started economies, alleviated rural poverty and saved large areas of fragile land from possible conversion to extensive farming. Between 1975 and 2000 cereal yields in south Asia increased by more than 50 percent while poverty declined 30 percent. Over the last 50 years world annual production of cereals, coarse grains, roots tubers and pulses and oil crops has grown from 1.8 to 4.6

billion tonnes (FAO, 2011). Growth in cereal yield and lower cereal prices significantly reduced food insecurity in the 1970–1980s when the number of undernourished actually fell despite rapid population growth. Overall the proportion of undernourished in the world population declined from 26 percent to 14 percent between 1969–1971 and 2000–2002 (FAO, 2009a; FAO, 2011).

It is now recognized that these gains in agricultural production and productivity were often made at the expense of the environment. Impacts included land degradation, salinization of irrigated areas, overextraction of groundwater, the buildup of pest resistance and loss of biodiversity, such that the production gains were unsustainable. In addition, in many instances, smaller-scale farmers were unable to participate or reap the rewards of scale.

3. Increasing crop production sustainably

Given the significant challenges to our food supply and the environment, sustainable intensification of agricultural production is emerging as a major priority for policy-makers and their international development partners. Sustainable intensification means producing more from the same area of land while reducing negative environmental impacts, increasing contributions to natural capital and the flow of environmental services (Godfray *et al.*, 2010). An ecosystem approach uses inputs such as seed, fertilizer, land, water, chemical or bio-pesticides, power and labour to complement the natural processes which support plant growth. Examples of these natural processes include: the action of soil-based organisms (that allow plants to access key nutrients; maintain a healthy soil structure which promotes water retention and the recharge of groundwater resources; and sequester carbon); pollination; natural predation for pest control. Farmers find that harnessing these natural processes can help to boost the efficiency of use of conventional inputs.

There is now widespread awareness of the importance of taking an ecosystem approach to intensifying crop production. A major study of the Future of Food and Farming up to 2050 prepared by the Government Office for Science in the United Kingdom, has called for substantial changes throughout the world's food system including sustainable intensification to simultaneously raise yields, increase efficiency in the use of inputs and reduce the negative impacts of food production (Foresight, 2011). The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) highlighted the need for policies that value, restore and protect ecosystem services, and address the needs of the world's small-scale and family farmers. It emphasized the need for a change in paradigm to encourage increased adoption of sustainable ecological agriculture and food systems and called for a shift from current farming practices to sustainable agricultural systems capable of providing significant productivity increases and enhanced ecosystem services (IAASTD, 2009).

Assessments in developing countries have shown how farm practices that conserve resources improve the supply of environmental services and increase productivity. A review of agricultural development projects in 57 low-income countries found that more efficient use of water, reduced use of pesticides and improvements in soil health had led to average crop yield increases of 79 percent (Pretty *et al.*, 2006). Another study concluded that agricultural systems that conserve ecosystem services by using practices such as conservation tillage, crop diversification, legume intensification and biological pest control, perform as well as intensive, high-input systems (Badgley *et al.*, 2007; FAO, 2011).

Sustainable crop production intensification (SCPI), when effectively implemented and supported, will provide the "win-win" outcomes required to meet the dual challenges of feeding the world's population and conserving the resources of the planet. SCPI will allow countries to plan, develop and manage agricultural production in a manner that addresses society's needs and aspirations, without jeopardizing the rights of future generations to enjoy the full range of environmental goods and services (FAO, 2011).

4. The need for a systems or integrated approach

Production is not the only element to consider when looking to meet increased demand for food. Sustainable intensification of crop production is pointless if optimizing one component (food crop production) results in inefficiencies elsewhere in a complex system also featuring livestock, fisheries, forestry and industrial components (e.g. biofuels). Similarly, throughout the food chain, post-harvest processing, transportation and distribution which do not support the supply of nutritious food to consumers will limit the benefit of efficiency gains in crop production.

While the challenge is clear at the global level, there can be no single blueprint for an ecosystem approach to crop production intensification on the ground, as it is dependent on local ecology, farming practices, markets etc. In implementing SCPI there are three elements that need to be considered: farmers; farming practices and technologies; and policies and institutions.

4.1 Targeted to and accessible by smallholder farmers

Although the principles and practices of sustainable intensification apply to both large- and small-scale farming, smallholder farmers are key to increasing food production sustainably. Approximately 85 percent of the farmers in developing countries are smallholders and there are about 500 million of them. They cultivate less than 2 ha of land each. Their number is increasing and their farms are getting smaller. They produce 80 percent of the food in developing countries and support some 2.5 billion people directly. Together smallholders use and manage more than 80 percent of farmland and similar proportions of other natural resources in Asia and Africa (IFAD, 2010). They are often economically efficient; they create employment, reduce poverty and improve food security. Unfortunately, however, 50 percent of the world's undernourished and 75 percent of the world's poor also live on and around such farms (FAO, 2009b).

Sustainable intensification has much to offer small farmers and their families by enhancing their productivity, reducing costs, building resilience to stress and strengthening their capacity to manage risk. Reduced spending on agricultural inputs can free resources for investment in farms and farm families' food, health, nutrition and education. Increases to farmers' net incomes will be achieved at lower environmental costs, thus delivering both private and public benefits. Overall gross domestic product growth generated in agriculture has large benefits for the poor and is at least twice as effective in reducing poverty as growth generated by other sectors (World Bank, 2007).

Clearly, increasing smallholder productivity will help to reduce hunger and poverty; it is inconceivable that Millennium Development Goal 1 can be achieved without addressing the needs of smallholder farmers.

4.2 Management practices and technologies

Sustainable crop production intensification must build on farming systems that offer a range of benefits to producers and society at large including high and stable production and profitability; adaptation and reduced vulnerability to climate change; enhanced ecosystem functioning and services and reductions in agriculture's greenhouse gas emissions and carbon footprint. These farming systems will be based on the following three technical principles:

I. simultaneous achievement of increased agricultural productivity and enhancement of natural capital and ecosystem services;

II. higher rates of efficiency in the use of key inputs including water, nutrients, pesticides, energy, land and labour;

III. use of managed and natural biodiversity to build system resilience to abiotic, biotic and economic stresses (FAO, 2011).

Successful approaches to SCPI will be built on the three principles listed above and implemented using a range of management practices and technologies including:

I. conservation agriculture – minimum soil disturbance and soil cover;
II. species diversification – use of high-yielding adapted varieties from good seed;
III. integrated plant nutrient management or IPNM based on healthy soils;
IV. Integrated Pest Management or IPM; and
V. efficient water management.

The appropriate mix of these management practices and technologies depends on local needs and conditions; given system complexity one size does not fit all. They will need to be applied in a complementary, timely and efficient manner in order to offer farmers appropriate combinations of practices to choose from and adapt.

4.2.1 Conservation Agriculture (CA)

CA can be described in terms of minimum mechanical soil disturbance, permanent organic cover and diversified crop rotations. Such practices can create stable living conditions for micro- and macro-organisms, providing a host of natural mechanisms supporting the growth of crops, which result in significant efficiency gains and decreasing needs for farm inputs, in particular power, time, labour (at least 25% less), fertilizer (30–50% less), agrochemicals (20% less pesticides) and water (28% less). Furthermore, in many environments, soil erosion is reduced to below the soil regeneration level or avoided altogether and water resources are restored in quality and quantity to levels that preceded putting the land under intensive agriculture.

Sustainable rice-wheat production

Sustainable productivity in rice-wheat farming systems was pioneered on the Indo-Gangetic Plain of Bangladesh, India, Nepal and Pakistan by the Rice-Wheat Consortium, an initiative of the CGIAR and national agriculture research centres. It was launched in the 1990s in response to evidence of a plateau in crop productivity, loss of soil organic matter and receding groundwater tables (Joshi *et al.*, 2010).

The system involves the planting of wheat after rice using a tractor-drawn seed drill, which seeds directly into unploughed fields with a single pass. Zero tillage wheat provides immediate, identifiable and demonstrable economic benefits. It permits earlier planting, helps control weeds and has significant resource conservation benefits, including reduced use of diesel fuel and irrigation water. Cost savings are estimated at US$52 per hectare, primarily owing to a drastic reduction in tractor time and fuel for land preparation and wheat establishment. Some 620 000 farmers on 1.8 million ha of the Indo-Gangetic Plain have adopted the system, with average income gains of US$180 to US$340 per household. Replicating the approach elsewhere will require on-farm adaptive and participatory research and development, links between farmers and technology suppliers and, above all, policy support to encourage new practices (including temporary financial incentives) (IFPRI, 2010; FAO, 2011).

4.2.2 Crops and varieties well adapted to local conditions

Adopting high-yielding varieties that best fit the cropping system and switching to crops more tolerant to diseases, pests and environmental stresses (including drought and increased temperatures) can help farmers to cope with less rainfall, salinity, or disease pressure and still produce a crop. The key is to ensure that sufficient farmers have access to improved adapted crop varieties through strengthened seed systems. Conservation and sustainable use of plant genetic resources for food and agriculture is necessary to ensure crop production and meet growing environmental challenges such as climate change.

Developing improved and adapted varieties

Sustainable intensification requires crop varieties that are resilient in the face of different agronomic practices, respond to farmers' needs in locally diverse agro-ecosystems and tolerate the effects of climate change. Important traits will include ability to cope with heat, drought and frost, increased input-use efficiency, and enhanced pest and disease resistance. Generally, it will involve the development of a larger number of varieties drawn from a greater diversity of breeding material.

It is unlikely that traditional public or private breeding programmes will be able to provide all the new plant material needed or produce the most appropriate varieties, especially of minor crops where research is not easily justified. Participatory plant breeding can help fill this gap, ensuring that more of the varieties developed meet farmer needs. For example, the International Center for Agricultural Research in the Dry Areas (ICARDA), together with the Syrian Arab Republic and other Near East and North African countries, has undertaken a programme of participatory plant breeding which maintains high levels of diversity and produces improved material capable of good yields in conditions of very limited rainfall (less than 300 mm per year). Farmers participate in the selection of parent materials and in on-farm evaluations. In Syria, the procedure has produced significant yield improvements and increased the resistance of the varieties to drought stress (Ceccarelli *et al.*, 2001; FAO, 2011).

4.2.3 Integrated Plant Nutrient Management (IPNM)

IPNM and similar strategies promote the combined use of mineral, organic and biological resources to balance efficient use of limited/finite resources and ensure ecosystem sustainability against nutrient mining and degradation of soil and water resources. For example, efficient fertilizer use requires that correct quantities be applied (overuse of Nitrogen [N] fertilizer can disrupt the natural N-cycle), and that the application method minimizes losses to air and/or water. Equally, plant nutrient status during the growing season can be more precisely monitored using leaf-colour charts, with fertilizer application managed accordingly. Efficient plant nutrition also contributes to pest management.

Urea deep placement for rice in Bangladesh

Throughout Asia, farmers apply nitrogen fertilizer to rice before transplanting by broadcasting urea onto wet soil, or into standing water, and then using one or more top-dressings of urea in the weeks after transplanting up to the flowering stage. Such practices are agronomically and economically inefficient and environmentally harmful. The rice plants use only about a third of the fertilizer applied (Dobermann, 2000), while much of the remainder is lost to the air through volatilization and to surface water run-off (FAO, 2011).

Deep placement of urea (N) briquettes can increase rice yields, while reducing the amount of urea used. In Bangladesh the average paddy yields have increased 20–25% and income from paddy sales increased by 10% while urea expenditures decreased 32% from the late 1990s to 2006 (IFDC, 2007).

4.2.4 Integrated Pest Management (IPM)

IPM encourages natural predation as a means of reducing the overuse of insecticides. In countries like India, Indonesia and the Philippines that followed green revolution strategies, subsequent adoption of IPM approaches coupled with the removal of insecticide subsidies, reduced insecticide use nationally by 50–75 percent, while rice production continued to increase annually. The ecosystem service delivered by natural predation replaced most chemical control, allowing other inputs and adaptive ecosystem management by farmers to secure and increase rice yields.

Reduced insecticide use in rice

Most tropical rice crops require no insecticide use under intensification (May, 1994). Yields have increased from 3 tonnes per ha to 6 tonnes through the use of improved varieties, fertilizer and irrigation. Indonesia drastically reduced spending on pesticides in rice production between 1988 and 2005 [Gallagher *et al.*, 2005]. However, in the past five years, the availability of low-cost pesticides, and shrinking support for farmers' education and field-based ecological research, have led to renewed high levels of use of pesticides with consequent large-scale pest outbreaks, particularly in Southeast Asia (Catindig *et al.*, 2009; FAO, 2011).

4.2.5 Water management

There are efficiency and productivity gains in crop water use that can be captured both "within" and "outside" the crop water system. For example, agricultural practice that reduces the soil evaporation reduces non-productive water consumption. In cropping systems adapted to seasonal or low evaporative demand of the atmosphere, it may be other types of agricultural practice (fertilizer, improved varieties, weed and pest management) that result in more productive consumption of water available in the root zone.

Deficit irrigation for high yield and maximum net profits

One way of improving water productivity is deficit irrigation, whereby water supply is less than full requirements and mild stress is allowed during specific growth stages that are less sensitive to moisture deficiency. The expectation is that any yield reduction will be limited and additional benefits are gained through diverting the saved water to irrigate other crops.

A six-year study of winter wheat production on the North China Plain showed water savings of 25 percent or more through application of deficit irrigation at various growth stages. In normal years, two irrigations of 60 mm (instead of the usual four) were enough to achieve acceptably high yields and maximize net profits. In studies carried out in India on irrigated groundnuts, production and water productivity were increased by imposing transient soil moisture-deficit stress during the vegetative phase, 20 to 45 days after sowing. Water stress applied during the vegetative growth phase may have had a favourable effect on root growth, contributing to more effective water use from deeper soil horizons. However, use of deficit irrigation requires a clear understanding of the soil-water (and salt) budgeting and an intimate knowledge of crop behaviour, as crop response to water stress varies considerably (FAO, 2002; FAO, 2011).

5. Enabling environment and policy framework

In preparing programmes, policy-makers need to consider issues that affect both SCPI and the development of the agricultural sector as a whole. National policies that seek to achieve economies of scale through value chain development and consolidation of land holdings may inadvertently exclude smallholders from the process, or reduce their access to productive resources. Improving transport infrastructure will facilitate farmers' access to supplies of fertilizer and seed, both critical for SCPI, and to markets. Given the high rate of losses in the food chain – in the order of 30 percent in both developing and developed countries – investment in processing, storage and cold chain facilities will enable farmers to capture more value from their production. Policy-makers can also promote small farmers' participation in SCPI by improving their access to production and market information through modern information and communication technology (FAO, 2011).

Farmers' assumptions, attitudes or cultural beliefs are often deeply ingrained. However, governments can create an enabling environment for the widespread uptake of productivity enhancing practices by farmers with appropriate policy frameworks, encouragement through participatory research and extension, the broadcast media, and formal and non-formal education, as well as through financial, tax and other incentives.

To encourage smallholders to adopt sustainable crop production intensification, it is not enough to demonstrate improved sustainability. Farming needs to be profitable, smallholders must be able to afford inputs and be sure of earning a reasonable price for their crops. Some countries protect income by fixing minimum prices for commodities; others are exploring smart subsidies on inputs, targeted to low income producers. Policy-makers also need to devise incentives for small farmers to use natural resources wisely for example through payments for environmental services and reduce the transaction costs of access to credit. In many countries, regulations are needed to protect farmers from unscrupulous dealers selling bogus seeds and other inputs; while inputs with negative environmental consequences need to be priced to reflect these aspects (FAO, 2011).

Production systems for SCPI are knowledge intensive and relatively complex to learn and implement. For many farmers, extensionists, researchers and policy-makers they represent new ways of doing business. There is thus an urgent need to build capacity and provide learning opportunities and technical support in order to improve the skills all stakeholders need. Major investment will be needed to rebuild research and technology transfer capacity in developing countries in order to provide farmers with appropriate technologies and to enhance their skills through approaches such as farmer field schools.

The shift to SCPI systems can occur rapidly when there is a suitable enabling environment or gradually in areas where farmers face particular agro-ecological socio-economic or policy constraints including a lack of necessary equipment. While some economic and environmental benefits will be achieved in the short term, a longer term commitment from all stakeholders is necessary in order to achieve the full benefits of such systems (FAO, 2011).

6. Key messages

In conclusion there are three key messages regarding the development and implementation of SCPI.

6.1 Sustainable crop production intensification (SCPI) requires a systems approach

Production is not the only element to consider in implementing SCPI; sustainable livelihoods and value chain approaches need to underpin the increase in productivity and diversification, so that one element is not optimized at the expense of another. SCPI harnesses ecosystem services such as nutrient cycling, biological nitrogen fixation, predation and parasitism, uses varieties with high productivity per external input and minimizes the use of technologies or practices that have adverse effects on human health or the environment.

SCPI represents a shift from current farming practices to sustainable agricultural systems capable of providing significant productivity increases and enhanced ecosystem services. Such systems are based on: simultaneous achievement of increased agricultural productivity and the enhancement of natural capital and ecosystem services; greater efficiencies in the use of key inputs, including water, nutrients, pesticides, energy, land and labour, using them to complement natural processes/ecosystem services and greater use of managed and natural biodiversity to build system resilience in farming systems to abiotic (drought and temperature changes), biotic (pests and diseases) and economic stresses (FAO, 2011).

6.2 Smallholder farmers in developing countries require special attention

The underlying principles and approaches to achieving SCPI are scale-neutral – they apply equally to large or small-scale farmers. However, sustainable intensification needs to be especially promoted among smallholder farmers in developing countries as they currently produce 80 percent of the food and use and manage more than 80 percent of the farmland in these countries. Increasing the productivity of smallholder farmers will help to reduce hunger and poverty among the 2.5 billion people dependent on these farms.

Smallholder farmers can benefit from SCPI as increased productivity enables them to gain from increased market demand for agricultural products, while making more efficient use of local resources and external inputs. These greater efficiencies will reduce costs leading to improved livelihoods, greater resilience to stress and ability to manage risks.

The way in which SCPI is implemented will differ markedly between smallholder farmers and the large mechanized farms typical of developed countries. SCPI provides a range of options that can be adapted to local needs while building on local knowledge and experience. SCPI promotes innovation and provides incentives for farmers to improve the local environment. A participatory approach to decision-making empowers farmers and strengthens communities. Increases to farmers' net incomes will be achieved at lower environmental cost, thus delivering both private and public benefits.

6.3 SCPI will not be achieved without significantly greater investment in agriculture

There is a need for greater policy and political support and for adequate incentives and risk mitigation measures to be in place for a shift to SCPI to take place. There is a need for large investments in infrastructure and capacity-building for the entire food chain including enhanced infrastructure, research, development and extension. The implementation of SCPI is knowledge intensive and will require new approaches to farmer education and extension as well as encouraging greater collaboration and communication among smallholders, researchers, government offices and the private sector to foster innovation, systematic approaches to agriculture and context focused knowledge production and sharing.

Policies and programmes for SCPI will cut across a number of sectors and involve a variety of stakeholders. Therefore a strategy for achieving sustainable intensification goals needs to be a cross-cutting component of a national development strategy. An important step for policy-makers is to initiate a process for mainstreaming strategies for sustainable intensification in national development objectives. SCPI should be an integral part of country-owned development programmes such as poverty reduction processes and food security strategies and investments. The roll out of sustainable intensification programmes and plans in developing countries requires concerted action with the participation of governments, the private sector and civil society (FAO, 2011).

References

Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M., Aviles-Vazquez, K., Samulon, A. & Perfect O, I. (2007). Organic agriculture and the global food supply. Renew Agric. Food Syst., 22: 86-108.

Catindig, J.L.A., Arida, G.S., Baehaki, S.E., Bentur, J.S., Cuong, L.Q., Norowi, M., Rattanakarn, W., Sriratanasak, W., Xia, J. & Lu, Z. (2009). In K.L. Heong &B. Hardy, eds. Planthoppers: New threats to the sustainability of intensive rice production systems in Asia, (pp.191-202, 221-231). Los Baños, Philippines, IRRI.

Ceccarelli, S., Grando, S., Shevestov, V., Vivar, H., Yayoui, A., El-Bhoussini, M and Baum, M. 2001. The ICARDA Strategy for global barley improvement. Aleppo Syria, ICARDA.

Dobermann, A. (2000). Future intensification of irrigated rice systems. J. E. Sheehy, P. L. Mitchel and B. Hardy, eds. Redesigning rice photosynthesis to increase yield, (pp. 229 – 247). Makati City, Philippines and Amsterdam, IRRI / Elsevier.

FAO. (2002). Deficit irrigation practices. Water reports No. 32, 51: 87-92.

FAO. (2009a). The State of Food Insecurity in the World: Economic crises – impacts and lessons learned. Rome, Italy.

FAO. (2009b). Food security and agricultural mitigation in developing countries: Options for capturing synergies. Rome, Italy

FAO. (2011). Save and Grow – A policy makers guide too the sustainable intensification of smallholder crop production. Rome, Italy

Foresight. (2011). The future of food and farming: Challenges and choices for global sustainability. Final Project Report. London, the government Office for Science.

Gallagher, K, Ooi, P., Mew T., Borromeo, Kenmore, P.E. & Ketelaar, J. (2005). Ecological basis for low-toxicity: Integrated pest management (IPM) in rice and vegetables. In J. Pretty, ed. The Pesticide Detox, (pp. 116 -134). London, Earthscan.

Godfray, C., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., and Toulmin, C. 2010. Food security: The challenge of feeding 9 billion people. Science, 327: 812-818.

IAASTD. (2009). Agriculture at the crossroads, by B.D. McIntyre, H.R. Herren, J. Wakhungu & R.T. Watson, eds. Washington, DC, USA.

IFAD. (2010) Rural Poverty Report 2011. New realities, new challenges: new opportunities for tomorrow's generation. Rome, Italy.

IFDC. "Bangladesh To Dramatically Expand Technology That Doubles Efficiency Of Urea Fertilizer Use." Science Daily, 25 Dec. 2007.

IFPRI. (2010). Zero tillage in the rice-wheat systems of the Indo-Gangetic Plains: A review of impacts and sustainability implications, by O. Erenstien. In D.J. Spielman & R. Pandya-Lorch, eds. Proven successes in agricultural development: A technical compendium to millions field. Washington, D.C, USA.

Joshi, P.K. Challa, J. & Virmani, S. M., eds. (2010). Conservation agriculture. Innovations for improving efficiency, equity and environment. New Delhi, India. New Delhi National Academy of Agricultural Science.

Pretty, J.N., Noble, A.D., Bossio, D., Dixon, J., Hine, R.E., de Vries, F.& Morison, J.I.L. (2006). Resource-conserving agriculture increases yields in developing countries. Environ Sci. Technol., 40: 1114-1119.

World Bank. 2007. World Development Report 2008. Washington, DC, International Bank for Reconstruction and Development and World Bank.

SUSTAINABILITY AND DIVERSITY ALONG THE FOOD CHAIN

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Abstract

Food and drink products play a central and fundamental role in daily life. Every day, some 480 million EU citizens rely on high quality food for their nutrition, health and well-being. The food and drink industry is the largest manufacturing sector in Europe with an annual turnover of €954 billion[1] and a leading manufacturing sector in Italy: with a turnover of €124 billion it is, along with agriculture, induced activity and distribution, the central element of the first economic sector of the country.[2]

There is an increasing societal awareness of the opportunities to improve the quality of life through healthy eating and of the contribution that sustainable production can make to improvement of the overall environment. The preferences of consumers for quality, convenience, diversity and health, and their justifiable expectations of safety, ethics and sustainable food production serve to highlight the opportunities for innovation.

As a response to these requirements Federalimentare, while already involved in the coordination of the European Technological Platform "Food for Life", has started up, together with the University of Bologna, ENEA, INRAN, the National Technology Platform "Italian Food for Life".

1. The food and drink industry[3]

The food and drink industry is the largest manufacturing sector in Europe with an annual turnover of €954 billion, half of which is generated by SMEs. The sector employs some 4.2 million people and is highly fragmented comprising some 310 000 companies, 99.1 percent of which are SMEs having less than 50 employees.

The Italian food and drink industry is one of the pillars of our national economy, representing the second manufacturing industry of our country with a turnover of 124 billion euros (of which 21 in export) and 32 300 companies – of which 6 500 with more than 9 employees and 2 600 with more than 19 employees – with over 410 000 employees.

Along with agriculture, induced activity and distribution, the food and drink industry is the central element of the first economic sector of the country. Industry buys and processes 70 percent of the national agricultural raw materials and is generally recognized as the ambassador of Made in Italy in the world considering that almost 80 percent of the Italian agrofood export is represented by high quality industry brands.

TURNOVER	124 bln C
EMPLOYMENT	410.000
NUMBER OF COMPANIES	32.3000 of which 6.500 companies → 9 employees 2.600 companies → 19 employees
EXPORT	21 bln C
IMPORT	17 bln C
TRADE BALANCE	4 bln C

Table 1. The Italian food and drink industry.
(Data and estimates Federalimentare, 2010)

The sector can claim several important factors and its image is a heritage extremely appreciated in Europe and in the world, divided in an enviable range of high-quality products and on a wide series of products of protected or controlled designation of origin which are leading in the international markets. It is a success due to the strict bonds of the Italian food and drink production with land and with the cultural heritage of Italy, and due to the safety standards, along with the ability to mix tradition and innovation of processes and of products. This is the reason why the sector is the target of a wide range of actions of imitation and forgery, especially on rich and demanding markets, like the American and the North European ones.

Nevertheless, in spite of these positive figures, the food and drink industry is penalized by some structural gaps that hold down its growth and its capacity to compete. The main factor that penalizes the growth of the food and drink industry is the

[1] Source: CIAA data and Trends 2010
[2] Source: Data and estimates Federalimentare 2010
[3] Source: Data and estimates Federalimentare 2010.

extreme fragmentation of production that comes even before the other bonds that restrain the whole system of our companies (structural lacks and logistics, exaggerated costs of production like energy, low quality offer of services for the companies). The sector is characterized by an extreme fragmentation, that sees only 20 percent of the companies above the threshold of 9 units and the remaining 30 000 firms tied to such a small dimension (3–9 units) that with the global trends adopted by our competitors it would seem unthinkable to realize any kind of competition. It is clear that the dimension of the companies is one of the major obstacles to the capacity to invest in research and innovation or to have access to the processes of transfer of technological innovations.
Instead, a strong impulse to the transfer of process and product innovation would certainly contribute to improve the position of competition of our food industry, especially of the small and medium enterprises.

2. Tradition and innovation[4]

About 25 percent of the turnover of the agrofood industry comes out from products for which innovation is an essential factor and which possess more added value; we are speaking of the so-called traditionally evolved, ready-to-eat sauces, spicy oils, fresh seasonings, frozen foods etc., and of the real new products, that are products with a high content of wellness and of services. If we consider the trends of the models of food consumption, this line of more "evolved" products is likely to reach more space in comparison with the so-called classic food (pasta, preserved foods, cheese, wine, oil), that at the moment reach about two-thirds of the entire turnover (65%), while the remaining 9 percent is represented by products of brand of origin and, by a smaller percentage, by organic products. So, if the internal market begins to show that research and innovation are one of the incentives of progress, the international one shows us that without capacity to innovate the risk to stay out of the market is going to

TRADITIONAL AND LOCAL FOOD	81,84 BNLEuro	66%
ADVANCED TRADITIONAL FOOD	19,84 BNL Euro	16%
TYPICAL QUALITY PRODUCTS (PDO, PGI, WINE...	11,53 BNL Euro	9,3% (of which 3 MLD Euro of EXPORT)
NEW PRODUCTS (novel, functional, healthy, ready to eat, etc...)	9,92 bnl Euro	8%
ORGANIC	0,87 BNL Euro	0,7%
TOTAL	124 BNL Euro	100% (of which 20 MLD Euro of EXPORT)

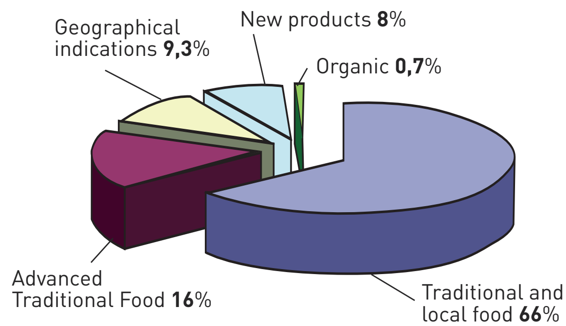

Table 2. Italian food and drink industry: turnover by product. (Data and estimates Federalimentare 2110)

become a reality, especially for our commodities. There is no doubt, therefore, that the success of our products rises from the capacity of our managers to mix tradition and innovation, giving due emphasis to applied research. During these last years our food companies, as a matter of fact have employed the most recent technologies, adapting them to the traditional gastronomical recipes, in order to create products easy to prepare, with higher security standards and a high level of quality. These results are possible only allocating resources every year to research. This financial commitment would not only mean an investment for the future but also an immediate response to the consumers' demands within the Italian style.
The Italian and international market of food products will be more and more affected by the changes in society (especially by the ageing and individualization), by the changes of the nutritional habits and by the way of life. For this reason the Italian food and drink industry is constantly involved in meeting the consumers' needs supplying products adapted to the various nutritional needs, considering as well the different ways of consumption that enable

[4] Source: Data and estimates Federalimentare 2010.

the consumer to make responsible choices and to follow a diet suitable to his lifestyle and the physical activity performed. The consumers themselves, especially the Italian and the European, are more and more in a position to recognize the real value of what they are buying, from the choice of the primary products, the technological features, to the attention given to the correct employ of natural resources, to logistics and packaging, from the point of view of the concept of global quality.

3. Food for Life[5]

As a response to these requirements Federalimentare, while already involved in Brussels coordinating the European Technological Platform "Food for Life", has started up, together with the University of Bologna, ENEA, INRAN, and with the most representative experts of the agro-industry sector in Italy, the National Technology Platform "Italian Food for Life". It is an instrument created with the aim to stimulate research and technological innovation in the agrofood sector at a national level in order to strengthen the scientific and technological basis of our food and drink industry, encouraging the development and international competition, especially to help the Small and Medium Enterprises. The Technology Platform "Italian Food for Life" is a unique opportunity not only to promote the coordination of the research activity of primary products and nutrition, assuring whether the direction, whether enough critical mass, but also to guarantee transfer of know-how to the companies.

4. Biodiversity and sustainability[6]

The food and drink industry is characterized by a very high diversity of different products and production processes. Europe's and Italy's traditions related to food are an expression of its cultural diversity and represent a clear asset on which the sector can build. Within the platform climate change, nature and biodiversity, health and quality of life and management of both natural resources and waste streams are all identified as areas in which particular attention needs to be focused in future years.

A sustainable food supply underpins the most basic requirements for quality of life.

4.1 Research on scenarios of future Italian food production and supply

Global climate change, the heavy dependency on fossil fuels and the political boundary conditions, are some aspects that will also influence the sustainability of the European and Italian food supply system, so they should be considered when studying scenarios.

4.2 Developing sustainable processing, packaging and distribution

Reduction in uses of energy, water and materials will require close links between raw material production, primary and secondary processing, packaging, waste management and reprocessing. Identification of improvement potentials from sustainability analysis will be an important driver for innovations that are directed towards new and novel technological solutions for food processing, packaging and transportation.

It is necessary an integrated approach towards the identification of the critical points of the process and the sustainability, so as to optimize methods and techniques that lead to an increase of competitiveness of the enterprises and to sustainable manufacturing and processing, packaging, transportation and distribution systems.

4.3 Developing and implementing sustainable primary food production

The study and preservation of local plant and animal biodiversity is a fundamental aspect for the development of sustainable production systems. While

[5] Sources: Data and estimates Federalimentare 2010, National Technology Platform "Italian Food for Life" Vision Document 2007, Implementation Action Plan 2008, Strategic Research and Innovation Agenda 2011.
[6] Sources: European Technology Platform "Food for Life" Vision Document 2005, Strategic Research Agenda 2007 and Implementation Action Plan 2008; National Technology Platform "Italian Food for Life" Vision Document 2006, Implementation Action Plan 2008, Strategic Research and Innovation Agenda 2011.

additional research needs to expand further knowledge on the interactions of biological cycles to enhance traditional food production, radically different primary food production systems may provide additional sources of food to traditional food production. Biotechnology may be used to produce desired crop biomass in a targeted way, and to provide plants with better sensory, nutritional and production properties. Further fine-tuning of production systems through precision farming and other high-tech solutions could increase the efficiency of primary food production. Alternative systems for animal husbandry should be evaluated, including the dimension of animal welfare.

4.4 Recycling and valorization of food industry surplus, by-products and wastes

Food industry raw materials, surplus, by-products and wastes/wastewaters are mostly wasted, and this reduces significantly the sustainability of the food industry.

The same matrices and products might become, after a proper pretreatment with biological or chemical/physical agents, cheap sources of fine-chemicals (antioxidants, vitamins etc.) and natural macromolecules (cellulose, starch, lignin, lipids, plant enzymes, pigments etc.). Their constituents might be also converted into more sophisticated chemicals (flavours, amino acids, vitamins, microbial enzymes etc.), biofuels (i.e. bioethanol, biodiesel, biogas and biohydrogen) and biobased products, such as biopolymers, fertilizers and lubricants, after tailored biocatalytic conversions or fermentations in suited biotech processes. The production of such a large array of high-value biomolecules and products from the currently wasted food industry surplus, co-products, by-products and wastes will markedly contribute to increase the overall sustainability and economics of several food production chains.

Conclusions

Improvements in sustainability have long-range benefits for the food industry in terms of reduced use of resources, increased efficiency and better governance.

The "Italian Food for Life" Technology Platform seeks to profitably provide citizens with safe, high-quality, health-promoting and affordable foods whilst meeting the increasing demands for sustainable food production as perceived from the economic, environmental and social perspectives.

ANIMAL GENETIC DIVERSITY AND SUSTAINABLE DIETS

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Abstract
The paper describes the links between human diets, expected changes in lifestyle and its impact on animal genetic resources for food and agriculture. Specifically, the focus is on the genetic resources of domesticated avian and mammalian species that contribute to food production and agriculture. The actual trends in combination with the growing demand for products of animal origin for human diets will inevitably lead to a shift in agricultural systems towards more intensive systems. This will most likely favour international transboundary breeds instead of local breeds. At species level, the shift towards poultry and pigs will continue. Whether products from intensive systems can contribute to a sustainable diet depends on the system's compatibility with regard to the rather complex concept of sustainable diets. It is concluded that providing sustainable diets can only be achieved with a combination of sustainable improvement of animal production and a combination of policy approaches integrating the full concept of sustainable diets, accompanied by awareness-raising for the value of animal genetic diversity and investing into research as a basis for sound decisions. Numerous research questions still require investigation, spanning different fields of science. With regard to livestock diversity and in view of the uncertainty of future developments and climate change this means to develop simple methods to characterize, evaluate and document adaptive and production traits in specific production environments.

1. Introduction

During the International Scientific Symposium on "Biodiversity and Sustainable Diets – United Against Hunger" held 3–5 November 2010 at FAO headquarters in Rome, experts agreed on a general concept: "Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources." With this definition, biodiversity is linked with human diets and with the diversity of livestock and livestock systems. However, trade-offs between the different levels of sustainability are not addressed. Hoffmann (2011) reviews different levels of sustainability and the trade-offs that occur between them, partly due to the high trophic level of livestock in the food web.

Agricultural biodiversity is a vital subset of biodiversity and the result of the interaction between the environment, genetic resources and management systems and practices used by culturally diverse peoples. Agrobiodiversity encompasses the variety and variability of animals, plants and micro-organisms that are necessary for sustaining key functions of the agro-ecosystem, including its structure and processes for, and in support of, food production and food security (FAO, 1999a).

The State of the Worlds Animal Genetic Resources for Food and Agriculture (FAO, 2007) describes the link between livestock biodiversity and food security. Genetically diverse livestock populations provide society with a greater range of options to meet future challenges. Therefore animal genetic resources (AnGR) are the capital for future developments and for adaptation to changing environments. If they are lost, the options for future generations will be severely curtailed. GTZ (2005) describes the preservation of diverse farming systems and high levels of biological diversity as a key precondition for eradicating hunger.

For livestock keepers, animal genetic diversity is a resource to be drawn upon to select stocks and develop (new) breeds. Even widely known, the term "breed" does not have a universally accepted biological or legal definition. However the term "breed" is used to identify distinct AnGR populations as units of reference and measurement. According to FAO (2007) breeds can be categorized as local (reported by only one country) or transboundary (reported by several countries). The latest assessment identifies 7 001 local breeds and 1 051 transboundary breeds (FAO, 2010a).

The breed concept originated in Europe and was linked to the existence of breeders' organizations. The term is now applied widely in developing countries, but it tends to refer to a sociocultural concept rather than a distinct physical entity. FAO uses the following broad definition of the breed concept, which accounts for social, cultural and economic differences between animal populations and which can therefore be applied globally in the measurement of livestock diversity: "either a sub-specific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity" (FAO, 1999b).

The paper describes the links between human diets, expected changes in lifestyle and its impact on animal genetic resources for food and agriculture. Specifically, the focus is on the genetic resources of domesticated avian and mammalian species that contribute to food production and agriculture.

2. Products and services provided by livestock

Livestock are used by humans to provide a wide range of products and services. Over time, a variety of breeds and types have been developed to provide these outputs in a wide range of production environments. Doubtless, foods derived from animals are an important source of nutrients (Givens, 2010) that provide a critical supplement and diversity to staple plant-based diets (Murphey and Allen, 2003). However, there are varied reasons for keeping livestock, which include providing manure, fibre for clothes and resources for temporary and permanent shelter, producing power, and serving as financial instruments and enhancing social status (Randolph *et al.*, 2007). This range of products and services supporting the livelihood strategies – especially of the poor – is a key feature of livestock (Alary *et al.*, 2011).

Until recently, a large proportion of livestock in developing countries was not kept for food. However, the growing demand for meat products is being met increasingly through industrial systems, where meat production is no longer tied to a local land base for feed inputs or to supply animal power or manure for crop production (Naylor *et al.*, 2005). As pointed out by FAO (2010b), the non-food uses of livestock are in decline and are being replaced by modern substitutes. Not only is animal draft power replaced by machinery and organic farm manure by synthetic fertilizers, but also insurance companies and banks replace more and more the risk management and asset functions of livestock.

3. Trends in consumption and production of livestock products

Animal source foods (ASF), mainly meat, milk and eggs provide concentrated, high quality sources of essential nutrients for optimal protein, energy and micronutrient nutrition (especially iron, zinc and vitamin B12). Access to ASF is believed to have contributed to the evolution of the human species' unusually large and complex brain and its social behaviour (Milton, 2003; Larsen, 2003). Today, ASF contribute a significant proportion to the food intake of Western societies (MacRae *et al.*, 2005), but play also an increasing role in developing countries. Since the early 1960s, consumption of milk per capita in the developing countries has almost doubled, meat consumption more than tripled and egg consumption increased by a factor of five (FAO, 2010b). The growing demand for livestock products in developing countries has been driven mostly by population growth, while economic growth, rising per capita incomes and urbanization were major determinants for increasing demand in a limited number of highly populated and rapidly growing economies, a development termed the "livestock revolution" (Delgado *et al.*, 1999; Pica-Ciamarra and Otte, 2009). This has translated into considerable growth in global per capita food energy intake derived from livestock products, but with significant regional differences. ASF consumption has increased in all regions except sub-Saharan Africa. The greatest increases occurred in East and Southeast Asia, and in Latin America and the Caribbean (FAO, 2010a). Structural changes in food consumption patterns occurred in South Asia, with consumer preference shifts towards milk and in East and Southeast Asia towards meat, while no significant changes could be detected in the other developing regions (Pica-Ciamarra and Otte, 2009).

Despite global average increases, undernutrition remains a large problem for those without access to animal source food and with food insecurity (Neumann *et al.*, 2010) especially for poor children and their mothers. High rates of undernutrition and micronutrient deficiency among the rural poor suggest that, despite often keeping livestock, they consume very little animal-based food. As iron, zinc and other important nutrients are more readily available in ASF than in plant-based foods, increased access to affordable animal-based foods could significantly improve nutritional status, growth, cognitive development and physical activity and health for many poor people (Neumann *et al.*, 2003). On the other hand, excessive consumption of livestock products is associated with increased risk of obesity, heart disease and other non-communicable diseases (WHO/FAO, 2003; Popkin and Du, 2003). However, the nutritional aspects of animal products as part of human diets are not the main focus of this publication.

4. Trends in breed diversity and livestock production systems

Diversity in AnGR populations is measured in different forms: our livestock breeds belong to different avian and mammalian species; thus species diversity can simply be measured as the number of species. At the subspecies level, diversity within and between breeds and the interrelationships between populations of breed can be distinguished (FAO, 2011a). Simply measuring breed diversity on the basis of number of breeds leads to biases due to the sociocultural nature of the breed concept. For example in Europe and the Caucasus (FAO, 2007), where for historical reasons many but often closely related breeds were developed, overestimation of between-breed diversity is likely. The within-breed diversity plays an important role for the total genetic variation of livestock; it may be lost due to random-genetic drift and inbreeding in small populations, usually local breeds. However, within-breed diversity is also threatened in international transboundary breeds as a side effect of efficient breeding programmes, usually focusing on rather narrow breeding goals. Various drivers influence the between and within diversity in AnGR. Those drivers overlap with drivers of change in global agriculture and livestock systems including population and income growth, urbanization, rising female employment, technological change and the liberalization of trade for capital and goods. Those drivers had and have direct impact on human diets where a shift away from cereal-based diets is at the same time cause and consequence of change in agriculture. The composition of the global agricultural production portfolio has changed considerably; development of the livestock sector was marked by intensification and a shift from pasture-based ruminant species to feed-dependent monogastric species (Pingali and McCullough, 2010).

Over the past decades, agriculture has achieved substantial increases in food production driven by growing demand, but accompanied by loss of biodiversity, including in AnGR, and degradation of ecosystems, particularly with respect to their regulating and supporting services (WRI, 2005; FAO, 2011b). Genetic erosion in plants was reported in cereals, but also vegetables, fruits and nuts and food legumes (FAO, 2010b). According to FAO (2011b), reliance on a lesser number of crops not only results in erosion of genetic resources but can also lead to an increased risk of diseases when a variety is susceptible to new pests and diseases. This means increased food insecurity. The same holds for AnGR. In this context it should be considered that a rapid spread of pathogens, or even small spatial or seasonal changes in disease distribution, possibly driven by climate change, may expose livestock populations with a narrow genetic basis to new disease challenges.

The situation in AnGR with regard to species diversity is alarmingly low: from the about 50 000 known avian and mammalian species only about 40 have been domesticated. On a global scale just five species show a widespread distribution and particularly large numbers. Those species are cattle, sheep, chicken, goats and pigs, the "big five" (FAO, 2007). Therefore, the majority of products of animal origin are based on quite narrow species variability with the same risks as described for plants.

The diversity of breeds is closely related to the diversity of production systems. Local breeds are usually based in grassland-based pastoral and small-scale mixed crop-livestock systems with low to medium use of external inputs. The many purposes for which livestock are kept are vanishing and being replaced by an almost exclusive focus on generating food for humans – meat, eggs and milk, and an ongoing trend away from backyard and smallholder livestock production to large-scale production systems. As a result of increased industrialization, livestock breeds adapted optimally to their habitat, in most cases not tailored to maximum meat or milk output, are increasingly being displaced by high performance breeds – usually transboundary breeds for use in high-external input, often large-scale, systems under more or less globally standardized conditions. In contrast to many local breeds, transboundary breeds provide single products for the market at high levels of output. Holstein Friesian Cattle – one of the most successful international dairy breeds – is spread almost all over the world and is reported to be present in at least 163 countries. Large white pigs are present in 139 countries; while in chicken, commercial strains dominate the worldwide distribution. Extrapolating the figures of FAO (2006) and assuming that the production increase between the early 2000s and 2009 is 100 percent attributable to industrial systems, we can now estimate that industrial systems which are based on a few international transboundary breeds, provide 79% of global poultry meat, 73% of egg and 63% of global pork production.

5. Possible future livestock production and consumption trends and their expected impact on AnGR

World population is projected to surpass 9 billion people by 2050. Most of the additional people will be based in developing countries, where population is projected to rise from 5.6 billion in 2009 to 7.9 billion in 2050, while the population of developed regions is expected to remain stable (UN, 2009). FAO projects that by 2050, global average per capita calorie availability could rise to 3 130 kcal per day, accompanied by changes in diet from staples to higher value foods such as fruit and vegetables, and to livestock products, requiring world agricultural production to increase by 70 percent from 2005/07 to 2050.

Based on past trends, FAO projects that globally, meat consumption per capita per year will increase from 41 kg in 2005 to 52 kg in 2050. In developing countries, the effect of the "livestock revolution" that led to fast growth of meat consumption and that was mainly driven by China, Brazil and some other emerging economies, is expected to decelerate. However, annual per capita meat consumption increases from 31 kg in 2005 to 33 kg in 2015 and 44 kg in 2050 are projected for developing countries. Annual per capita meat consumption in developed countries is projected to increase from 82 kg in 2005 to 84 kg in 2015 and 95 kg in 2050 (OECD-FAO 2009; Bruinsma, 2009; FAO, 2010a). Given that net trade in livestock products is a very small fraction of production, the production projections mirror those of consumption.

Thornton (2010) gives a comprehensive overview on possible modifiers of future livestock production and consumption trends, listing competition for resources, climate change, sociocultural modifiers, ethical concerns and technological development. Satisfying the growing demand for animal products while at the same time sustaining productive assets of natural resources is one of the major challenges agriculture is facing today (Pingali and McCullough, 2010). At the same time as the livestock sector is a major contributor to greenhouse gas emissions, climate change itself may have a substantial impact on livestock production systems. Hoffmann (2010) gives a comprehensive overview on the consequences of climate change for animal genetic diversity, discussing the differences between developing and developed countries.

The environmental impacts of livestock production occur at local, regional and global levels (FAO, 2006). The particularly rapid growth of the livestock sector implies that much of the projected additional cereal and soybean production will be used for feeding enlarging livestock populations, resulting in increasing competition for land, water and other productive resources. This in turn puts upward pressure on prices for staple grains, potentially reducing food security. A further concern in relation to products of animal origin is livestock's contribution to climate change and pollution. The projected need for additional cropland and grassland areas implies further risks of deforestation and other land-use changes, e.g. conversions of semi-natural grasslands. This will not only lead to loss of biodiversity, but also to greenhouse gas and nitrogen emissions (FAO, 2010a; Westhoek *et al.*, 2011). More research is needed related to livestock-water interactions. Such concerns are highly relevant when talking about sustainable diets.

Together with an increasing urbanization and globalization, market requirements will change. As market requirements are standardized and allow for little differentiation, some traditional and rare breeds might face increasing marketing difficulties. Loss of small-scale abattoirs, often due to food safety regulation, can reduce the ability for breeds to enter niche markets or product differentiation. National strategies for livestock production do not reflect the need for a genetic pool of breeding stock. Although breeding has to focus on what the market wants (mass or niche market), other factors also have to be taken into account. The choice of breeds/breeding used in the livestock sector needs to ensure the profitability of the farm, safeguard animal health and welfare, focus on conserving genetic diversity, and promote human health.

Modelling results indicate that the main points of intervention to reduce the environmental impacts of livestock production are: changes in nutrient management, crop yields and land management, husbandry systems and animal breeds, feed conversion and feed composition, reduction in food losses, and shifts in consumption (Stehfest *et al.*, 2009; Westhoek *et al.*, 2011; FAO, 2011b).

Due to the many synergies between enhancing production and reducing costs, it is already common practice to improve production efficiency. The changes in husbandry systems and animal breeds, and feed conversion and feed composition, will favour intensive livestock systems in which good feed conversion efficiency leads to reduced GHG emissions per unit of meat, milk etc. produced, which can be judged positively with regard to contributing products to sustainable diets. However, soil and water pollution and contamination are frequently found in intensive production areas (FAO, 2010a). Increasing concentrate feed efficiency will lead most likely to shift with regard to the species away from ruminants towards monogastric species like poultry and pigs (FAO, 2010a). On the breed level, local breeds will more and more be replaced by transboundary breeds, leading to a further loss of local breeds and their manifold functions. Besides the loss of between-breed diversity an additional loss of within-breed diversity can be expected due to the further pressure on increasing yields of transboundary breeds by applying effective breeding programmes focusing on rather narrow breeding goals. Such losses due to effective breeding programmes might even be faster than in the past due to application of new biotechnologies.

Intensification of livestock production systems, coupled with specialization in breeding and the harmonizing effects of globalization and zoosanitary standards, has led to a substantial reduction in the genetic diversity within domesticated animal species (FAO, 2007). The risk for breed survival in the past was highest in regions that have the most highly-specialized livestock industries with fast structural change and in the species kept in such systems. Globally, about one-third of cattle, pig and chicken breeds are already extinct or currently at risk (FAO, 2010a). According to the last status and trends report of AnGR (FAO, 2010a) a total of 1 710 (or 21 percent) of breeds are classified as being "at risk".

Recent studies proposed that the consumption of farm animal products must be curtailed to reduce anthropogenic greenhouse gas emissions (Stehfest *et al.*, 2009). Others propose lowering meat demand in industrialized countries (Grethe *et al.*, 2011) which, although having only a small effect on food security in developing countries, would have positive effects for human health, result in a less unequal per capita use of global resources, lower greenhouse gas emissions, and could ease the introduction of higher animal welfare standards (see also Deckers, 2010).

A further option to fulfill the globally growing demand for animal source products could be the use of "artificial" meat or *in vitro* produced meat. In this trajectory, changes in food composition could improve health characteristics, and closed industrial production technology may result in more hygienic and environmental friendly characteristics than "traditional" meat (Thornton, 2010). While this may contribute, e.g. to the health aspect of a sustainable diet, it may possibly not fulfill the criterion of "cultural acceptance". Also, a large-scale development and uptake of *in vitro* meat will have severe effects on the livestock sector and most likely a negative effect on the diversity of AnGR. *In vitro* meat and food fortification also contradict the concept of sustainable diet which stresses the importance of food-based approaches (Allen, 2008).

Finally, the reduction of food losses will be critical, as they imply that huge amounts of the resources used in and GHG emissions caused by production of food are used in vain. Waste disposal releases even more GHG. ASF, being highly perishable and connected to food safety risks, incur high losses along the chain. Losses of meat and meat products in all developing regions are distributed quite equally throughout the chain, while in industrialized regions, about 50 percent of losses occur at the end of the chain due to high per capita meat consumption combined with large waste proportions by retailers and consumers. Waste at the consumption level makes up approximately 40–65 percent of total milk food waste in industrialized regions. For all developing regions, waste of milk during post-harvest handling and storage, as well as at the distribution level, is relatively high (FAO, 2011b).

In summary, the actual trends in combination with the growing demand for products of animal origin for human diets will inevitably lead to a shift in agricultural systems towards more intensive systems. This will most likely favour international transboundary breeds instead of local breeds. At species level, the shift towards poultry and pigs will continue.

Whether products from intensive systems can contribute to a sustainable diet depends on the system's compatibility with regard to the rather complex concept of sustainable diets namely being protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources. However, even if many aspects to contribute to a sustainable diet might be fulfilled in more intensive systems, a loss of AnGR appears to be quite likely at global level.

6. Solutions with focus on sustainable diets favouring diversity of AnGR

Past efforts to increase yields and productivity have been undertaken mainly within a framework that has aimed to control conditions and make production systems uniform (FAO/PAR, 2010), which allows the use of uniform breed and being therefore not beneficial for the diversity of AnGR. This has led to a narrow set of breeds and management practices. Inevitably, cultural and social roles of livestock will continue to change, and many of the resultant impacts on food security may not be positive (Thornton, 2010). The scenarios described above do not give rise to a bright future for AnGR's diversity even if sustainable diets are propagated. However, there is hope because there is already a wide range of agricultural practices available to improve production in sustainable ways (e.g. FAO/IAEA 2010).

Focusing on local and regional rather than global (i.e. GHG) aspects of sustainability also has its drawbacks. Measures such as improved animal welfare may lead to less efficient production, thereby may just shift the negative environmental impact elsewhere; other measures may lead to higher costs for farmers. However, Westhoek (Westhoek *et al.*, 2011) assume that, if done properly, such measures would lead to lower societal costs by reducing local environmental impacts, animal welfare problems and public health risks. Aiming for manifold objectives with regard to environmental aspects of livestock keeping like reduction of greenhouse gases, maintenance of biodiversity etc., will lead to different, locally tailored solutions. Manifold objectives might add value to AnGR's diversity. There exist also agricultural systems that are reliant on biological processes and on natural properties of agro-ecosystems to provide provisioning, regulating, supporting and cultural services. Such systems are a prerequisite for production of food for sustainable diets. Besides traditional systems a range of different innovative approaches to agricultural production exist, seeking to combine productivity and increased farmer incomes with long-term sustainability (FAO/PAR, 2011). In European countries, there is an increased emphasis on, and economic support for, the production of ecosystems goods and services, with a possibly positive effect on the role of local breeds and survival chances for small-scale abattoirs.

Arguments in favour of low-input breeds are based on the multiple products and services they provide, mostly at regional and local level. Firstly, their ability to make use of low-quality forage results in a net positive human edible protein ratio. Secondly, under appropriate management, livestock kept in low external input mixed and grazing systems provide several ecosystem services. Thirdly, as a result, and linked to local breeds' recognition as cultural heritage, linkages to nature conservation need to be further explored and strengthened (Hoffmann, 2011). All this is in harmony with the qualities of a sustainable diet.

In this context the ability of livestock, especially ruminants, to transform products not suitable for human consumption, such as grass and by-products, into high-value products such as dairy and meat, plays a role. Permanent grasslands are an important carbon sink and harbours of biodiversity.

One of the six priority targets of the 2011 EU Biodiversity Strategy is "to increase EU contribution to global efforts to avoid biodiversity loss". The accompanying impact assessment suggests that approximately 60 percent of agricultural land would need to be managed in a way that supports biodiversity to meet this target (including both extensively and intensively managed areas under grass, arable and permanent crops.

In Europe, so-called High Nature Value Farmlands make up approximately 30 percent of grasslands (EU15); they are considered to be part of Europe's cultural heritage and are mostly Natura 2000 sites. However, only an estimated 2–4 percent of dairy production and around 20 percent of beef production comes from high nature value grasslands. The majority of livestock production in Europe originates from intensively managed permanent or temporary grasslands, stimulated by fertilizer application and often sowed with high-yielding grass varieties, and from cropland (Westhoek *et al.*, 2011).

At global levels, distinctions between different types of grasslands, is even more difficult. Grasslands occupy about 25% of the terrestrial ice-free land surface. In the early 2000s they harboured between 27% and 33% of cattle and small ruminant stocks, respectively, and produced 23% of global beef, 32% of global mutton and 12% of milk (FAO, 2006). There is sufficient intensification potential in such extensive systems without having to change the breed base; a recent life cycle analysis for the dairy sector also showed a huge potential for moderate efficiency gains in developing countries (FAO, 2010c). On the contrary, well adapted, hardy breeds are advantageous in utilizing the vast areas under rangelands (FAO, 2006). In view of the uncertainty for future developments a wide diversity of AnGR is the best insurance to cope with unpredictable effects.

The main criticisms of ecological approaches were summarized during an expert workshop on biodiversity for food and agriculture (FAO/PAR, 2011) as follows: (i) adoption of ecological approaches to farming reflects a romantic and backward-looking perspective, (ii) they will require even larger subsidies, and (iii) they are labour and knowledge intensive. To overcome this scepticism, innovation and development for new approaches will be essential, while a critical assessment of existing research results might be advisable, because most cost-benefit analyses comparing high-input systems with sustainable agricultural systems tend not to account for the manifold benefits agricultural systems can provide (FAO/PAR, 2011).

The recognition of the value of nutritional and dietary diversity is becoming an important entry point for exploring more ecologically sustainable food systems. A key role might be played by consumers when getting more access to information and control over consumption. Undoubtedly, use of diversity requires significant knowledge and skills. Nevertheless there are questions regarding the robustness of consumers' preferences regarding organic and local food, particularly in times of considerable economic uncertainty (Thornton, 2010). Limited economic resources may shift dietary choices towards cheap, energy-dense, convenient, and highly palatable diets providing maximum energy (Drewnowski and Spencer, 2004). Consumption shifts, particularly a reduction in the consumption of livestock products, will not only have environmental benefits (Stehfest *et al.*, 2009), but may also reduce the cardiovascular disease burden (Popkin and Du, 2003). However, changing consumption patterns is a slow cultural process.

7. Conclusions

There is no question that demands for animal products will continue to increase in the next decades and a further push to enhance livestock productivity across also production systems is needed that takes the environmental footprint of livestock production into account. At local level, there are many agreements between environmental sustainability goals, sustainable production and providing sustainable diets. However, many of the required new technologies to increase resource efficiencies at global level will accelerate the structural change of the sector towards more intensive systems and thereby the losses of animal genetic diversity even if sustainable diets are aimed at. If the goal is providing sustainable diets, avoiding the erosion of genetic diversity must be more spotlighted.

Providing sustainable diets can only be achieved with a combination of sustainable improvement of animal production and a combination of policy approaches integrating the full concept of sustainable diets, accompanied by awareness raising for the value of biodiversity and investing in research as a basis for sound decisions. Numerous research questions still require investigation, spanning different fields of science. With regard to livestock diversity and in view of the uncertainty of future developments and climate change this means to develop simple methods to characterize, evaluate and document adaptive and production traits in specific production environments. The lack of such data is currently one of the serious constraints to effective prioritizing and planning for the best use of animal genetic resources measures in a sustainable development of the livestock sector. Intensifying research to develop life-cycle assessments and to include delivery of ecosystem services in the analysis recognizing and rewarding the sustainable use of biodiversity in well-managed rangelands with local breeds will also be one major task.

The concept of sustainable diet and the essential role of AnGR, needs to be addressed through awareness and educational programmes. Eating means not just ingesting food, but it is also a form of enjoyment and cultural expression.

References

Alary, V., Corniaux, C., Gautier, D. (2011). Livestock's Contribution to Poverty Alleviation: How to Measure It? Retrieved June 20, 2011 from http://www.sciencedirect.com/science/article/pii/S0305750X11000271

Allen, L.H. (2008). To What Extent Can Food-Based Approaches Improve Micronutrient Status? Asia Pacific Journal of Clinical Nutrition, 17(S1), 103-105.

Bruinsma, J. (2009). The resource outlook to 2050: By how much do land, water and crop yields need to increase by 2050?. In How to feed the World in 2050. Proceedings of a technical meeting of experts, Rome, Italy, 24-26 June 2009 (pp. 1-33). Food and Agriculture Organization of the United Nations: Rome, Italy.

Deckers, J. (2010). Should the consumption of farm animal products be restricted, and if so, by how much? Food Policy , 35, 6, 497-503.

Delgado, C., Rosegrant, M., Steinfeld H., Ehui S., Courbois C. (1999). Livestock to 2020. The next food revolution. In Food, Agriculture and the Environment Discussion Paper, 28. Washington, USA: IFPRI.

Drewnowski, A., & Spencer, S.E., (2004). Poverty and obesity: The role of energy density and energy cost. The American Journal of Clinical Nutrition, 79 (1), 6-16.

FAO (1999a). The Multifunctional Character of Agriculture and Land: the energy function. In Cultivating our future. Background Papers on "The Multifunctional Character of Agriculture and Land" (Background paper 1). Food and Agriculture Organization of the United Nations: Maastricht, The Netherlands.

FAO (1999b). The global strategy for the management of animal genetic resources: executive brief. Initiative for Domestic Animal Diversity. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2006). Livestock's long shadow – environmental issues and options. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2007). The State of the World 2007. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2010a). Status and trends report on animal genetic resources – 2010, CGRFA/WG-AnGR-6/10/Inf. 3. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2010b). The State of Food and Agriculture 2009. Livestock in the Balance. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2010c). Greenhouse Gas Emissions from the Dairy Sector. A Life Cycle Assessment. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2011a). Draft guidelines on phenotypic characterization. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2011b). The State of Food and Agriculture 2010-2011.

Women in agriculture. Closing the gap for development. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO/IAEA (2010). In Proceedings of the international Symposium "Sustainable improvement of animal production and health" organized by the joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture in cooperation with the Animal Production and Health Division of FAO. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO/PAR (2010). Biodiversity for Food and Agriculture. Contributing to food security and sustainability in a changing world. Rome, Italy: Food and Agriculture Organization & Platform for Agrobiodiversity Research.

Givens, D.I. (2010). Milk and meat in our diet good or bad for health?. Animal, 4, 12, 1941-1952.

Grethe, H., Dembélé, A., Duman, N. (2011). How to feed the world's growing billions? Understanding FAO world food projections and their implications. Heinrich Böll Foundation & WWF: Berlin, Germany.

Gustavsson, J. (Eds), Cederberg, C., Sonesson, U., van Otterdijk, R., Meyback, A. (2011b). Global food losses and food waste. Extent, causes and prevention. Rome, Italy: Food and Agriculture Organization of the United Nations.

GTZ (2005). Zwischen Natur und Kultur: Mensch, Ernährung und biologische Vielfalt. Where nature and culture meet: People, food and biodiversity. Eschborn, Germany: Gesellschaft für Technische Zusammenarbeit.

Hoffmann, I. (2010). Climate Change in Context: Implications for Livestock Production and diversity. In N.E. Odongo, M. Garcia, G.J. Vilojen (Eds), Sustainable improvement of Animal Production and Health (pp.33-44). Rome, Italy: Food and Agriculture Organization of the United Nations.

Hoffmann, I., (2011). Contribution of low-input farming to biodiversity conservation. In First Low Input Breeds Workshop, 15-16 March 2011. Wageningen, The Netherlands.

Larsen, C.S., (2003). Animal Source Foods and Human Health during Evolution. The Journal of Nutrition, 133, 11, 3893S–3897S.

MacRae, J., O'Reilly, L., Morgan P. (2005). Desirable characteristics of animal products from a human health perspective. Livestock Production Science,94, 1, 95-103.

Milton, K. (2003). The Critical Role Played by Animal Source Foods in Human (Homo) Evolution. The Journal of Nutrition, 133, 11, 3886S–3892S.

Murphey, S.P., & Allen, L.H. (2003). Nutritional importance of animal source foods. The Journal of Nutrition, 133,11, 3932S-3935S.

Naylor, R., Steinfeld, H., Falcon, W., Galloway, J., Smil, V., Bradford, E., Alder, J., Mooney, H. (2005). Agriculture: Loosing the links between livestock and land. Science, 310, 5754, 1621-1622.

Neumann, C.G., Bwibo, N.O., Murphy, S.P., Sigman, M., Whaley, S., Allen, L.H., Guthrie, D., Weiss, R.E., Demment, M.W. (2003). Animal Source Foods Improve Dietary Quality, Micronutrient Status, Growth and Cognitive Function in Kenyan School Children: Background, Study Design and Baseline Findings. Journal of Clinical Nutrition, 133, 11, 3941S–3949S.

Neumann, C.G., Demment, M.W., Maretzki, A., Drorbaugh, N., Galvin, K.A. (2010). Benefits, Risks, and Challenges in Urban and Rural Settings of Developing Countries. In H. Steinfeld, H.A. Mooney, F. Schneider, L. E. Neville (Eds.), Livestock in a Changing Landscape, Vol. 1: Drivers, Consequences, and Responses (pp.221-248). Washington, Covelo, London: Islandpress.

OECD-FAO (2009). Agricultural Outlook 2009-2018. Rome, Italy: Food and Agriculture Organization of the United Nations.

Pica-Ciamarra, U., & Otte, J. (2009). The 'Livestock Revolution': Rhetoric and Reality. In Pro-Poor Livestock Policy Initiative, (pp. 05-09). Rome, Italy: Food and Agriculture Organization of the United Nations.

Pingali, P., & McCullough, E. (2010). Drivers of Change in Global Agriculture and Livestock Systems. In H. Steinfeld, H.A. Mooney, F. Schneider, L. E. Neville (Eds.), Livestock in a Changing Landscape, Vol. 1: Drivers, Consequences, and Responses (pp.5-10). Washington, Covelo, London: Islandpress.

Popkin, B.M., & Du, S. (2003). Dynamics of the Nutrition Transition toward the Animal Foods Sector in China and its Implications: A Worried Perspective. Journal of Clinical Nutrition, 133, 11, 3898S–3906S.

Randolph, T.F., Schelling, E., Grace, D., Nivholson, C.F., Leroy, J.L., Cole, D.C., Demment, M.W., Omore, A., Zinsstag, J., Ruel, M. (2007). The role of livestock in human nutrition and health for poverty reduction in developing countries. Journal of Animal Science, 85, 2788-2800.

Rischkowsky, B., & Pilling, D.(Eds) (2007). The state of the world's animal genetic resources for food and agriculture. Rome, Italy: Food and Agriculture Organization of the United Nations.

Stehfest E., Bouwman, L., van Vuuren, D.P., den Elzen, M.G.J., Eickhout, B., Kabat, P. (2009). Climate benefits of changing diet. Climatic Change, 95, 83–102.

Thornton, P.K. (2010). Livestock production: recent trends, future prospects. Philosophical Transactions of the Royal Society, B,365, 2853–2867.

UN (2009). World Population Prospects. The 2010 Revision. Retrieved June 20, 2011 from http://esa.un.org/wpp/index.htm

Westhoek, H., Rood, T., van den Berg, M., Janse, J., Nijdam, D., Reudink, M., Stehfest, E. (2011). The Protein Puzzle. The consumption and production of meat, dairy and fish in the European Union. The Hague, The Netherlands: PBL Netherlands Environmental Assessment Agency.

WHO/FAO (2003). Diet, nutrition and the prevention of chronic diseases. Report of a joint WHO/FAO Expert Consultation. WHO Technical Report series 916. Geneva, Switzerland: WHO.

WRI (2005). Ecosystems and Human Well-being: Biodiversity Synthesis. Millennium Ecosystem Assessment. Washington DC, Washington, USA: World Resources Institute.

AQUATIC BIODIVERSITY FOR SUSTAINABLE DIETS: THE ROLE OF AQUATIC FOODS IN FOOD AND NUTRITION SECURITY

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Abstract

Aquatic foods make a significant contribution to improve and diversify diets and promote nutritional well-being for many people. However, fisheries resources have been poorly managed for decades and are fully exploited, sometimes even overexploited. The increasing demand for aquatic foods will therefore be met by reducing post-harvest losses and diversion of more fish into direct human consumption, but above all by an increasing aquaculture production. Aquaculturists are optimistic that far more fish can be produced, however, the availability of fishmeal and fish oil, the main ingredients for aquaculture puts with the present technology, a limit to this development. Any growth of sector as experienced during the past decades will therefore more likely be linked with the sustained supply of terrestrial feed ingredients. This development is raising concerns that aquaculture products might get a nutrition profile differing from their wild counterpart, particularly in relation to the content of the beneficial long-chained omega-3 fatty acids. The importance for biodiversity of the strong development of aquaculture is outstanding, as only a handful of species are commercially cultivated, while the world capture fisheries includes a huge range of species. The increasing concern for a sustainable use of fisheries and aquaculture resources has resulted in the development of principles and standards where the FAO Code of Conduct for Responsible Fisheries is becoming a reference. This has led to frameworks, agreements and guidelines aiming at securing both human and animal health, protecting biodiversity and promoting environmental sustainability. An increased awareness among consumers about the sustainability of fisheries resources has emerged in the Northern Hemisphere during recent years, and the fisheries sector is responding by developing a number of certification schemes and labels certifying that their products are sustainable. Increased emphasis on aquatic ecosystems, such as rice fields, should also be mentioned, since a more intensified agriculture sector is challenging this unique source of aquatic foods.

Introduction

Aquatic foods, comprising fish, other aquatic animals and aquatic plants, have been significant sources of food and essential nutrients since ancient times. The wealth of aquatic resources has also provided employment and livelihoods, and has been regarded as an unlimited gift from nature. However, with increasing knowledge, we also know these resources are finite and need to be properly utilized and managed in order to secure their important contribution to diets and economic activities of a growing world population.

Aquatic foods, from both cultured and captured sources, make a significant contribution to improve and diversify dietary intakes and promote nutritional well-being among most population groups. Eating fish is part of the cultural traditions of many people, and in some populations, fish and fishery products are a major source of food and essential nutrients, and there may be no other good alternative and affordable food sources for these nutrients.

Fish has a highly desirable nutrient profile and can provide an excellent source of high quality animal protein that is easily digestible and of high biological value. Fatty fish, in particular, is an extremely rich source of omega-3 polyunsaturated fatty acids (PUFAs) that are crucial for normal growth and mental development, especially during pregnancy and early childhood (Lewin *et al.*, 2005; Martinez, 1992). It is also established that fish in the diet in most circumstances lowers the risk that women give birth to children with suboptimal development of the brain and neural system that may occur if not eating fish (FAO/WHO, 2011).

Among the general adult population, consumption of fish, and in particular oily fish, lowers the risk of CHD mortality (Mozaffarian and Rimm, 2006). Fish and other aquatic foods are also rich in vitamins such as vitamin A, D and E, and also vitamins from the B complex. Minerals such as calcium, phosphorus, zinc, selenium, iron and iodine in marine products are abundant in most aquatic foods, and fish can play an extremely important role as a very good source of essential nutrients, particularly as a source of micronutrients, where other animal source foods are lacking.

More than one billion people, within 58 developing and low-income food-deficit countries, depend on fish as the primary source of animal protein. Fish is a unique food that could be used to address almost all the major malnutrition disorders. Beyond providing food, aquaculture and fisheries also strengthen people's capacity to exercise their right to food through employment, community development, generating income and accumulating other assets.

Sustainability of aquatic resources as food

The global production of marine capture fisheries was about 80 million tonnes in 2008. The stocks of the top ten species account for about 30 percent of the world marine capture fisheries production, most of them fully exploited (Figure 1). The widespread failure to manage fishery resources properly, has resulted in a situation where some 32% of stocks are overexploited, and 53% of the stocks are fully exploited, leaving only 15% of the stocks with a potential for increased capture and biodiversity in foods based on capture fisheries. There is general scientific agreement that significantly more cannot be produced from wild fish populations (FAO, 2011a).

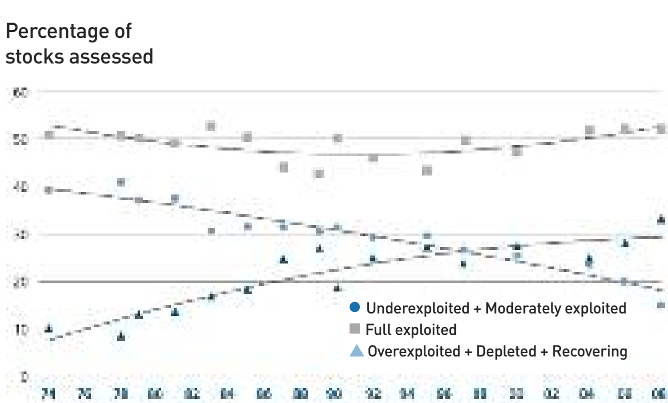

Figure 1. Global trends in the state of world marine stocks since 1974 (FAO, 2011a).

However, total global fish production has continued to rise, amounting to 142 million tonnes in 2008. The balance is made up by production from aquaculture, which amounted to 52.5 million tonnes in 2008, contributing 46 percent to the total foodfish production. Although there is no association between resource sustainability and health, the issue of sustainability must be considered if proven health benefits lead to an increased demand for seafood. With the known wide range of benefits from seafood consumption, it is pertinent to consider whether increased production is possible.

The increasing demand for fish will mainly be provided by increased aquaculture production. However, the increasing demand for fisheries products is also encouraging a better use of available, but limited, resources. FAO is encouraging technology and knowledge that could help the fisheries industry and fish processors to reduce waste and increase the amount of fish ending up as food.

Post-harvest losses of high quality fish are also a challenge due to poor handling of fish and fisheries products. In some cases 20 percent of fish landed are lost before reaching the consumer due to poor hygiene facilities and handling. Poor handling also causes big physical losses of fish, as well as economic losses due to lower quality and value of the end product. As demand for fisheries products will increase in the future and acknowledging the important role of the fisheries sector in food and nutrition security, the economy and livelihoods of many vulnerable populations, sharing knowledge on handling and storing of a perishable product such as fish should be given high priority.

Increased focus on improving the utilization of fish species of low value, such as the Peruvian anchoveta should also be encouraged. The anchoveta has traditionally been processed into fish oil and fishmeal, but is a good example of an excellent fish with a potential for direct human consumption; very high nutritional value, and affordable for most people. Although challenges such as cultural acceptance and conflict with the high demand for fishmeal and oil, direct human consumption would in many cases be a better use of the limited fisheries resources. During the last ten years the consumption of Peruvian anchoveta has actually increased significantly, but is still less than 5 percent of the total catches.

Feeding the aquaculture sector

It is anticipated that an additional 27 million tonnes of aquatic food will be required by 2030 considering the projected population growth and maintaining the present per capita consumption. Availability of feed will be one of the most important inputs if aquaculture has to maintain its sustained growth to meet the demands of aquatic foods. Total industrial compound aquafeed production has increased almost fourfold from 7.6 million tonnes in 1995 to 29.3 million tonnes in 2008, representing an average growth rate of 10.9 percent per year (Tacon *et al.*, 2011). Compound feeds are used both for the production of lower-value (in marketing terms) food-fish species such as non-filter feeding carps, tilapia, catfish and milkfish, as well as higher-value species such as marine finfish, salmonids, marine shrimp, and freshwater eels and crustaceans.

The aquaculture sector is now the largest user of fishmeal and fish oil (Tacon *et al.*, 2011). However, it is projected that over the next ten years or so, the total use of fishmeal by the aquaculture sector will decrease while the use of fish oil will probably remain around the 2007 level (Tacon *et al.*, 2011). The reason for this is due to decreased fishmeal and fish oil supplies; tighter quota setting and better enforced regulation of fisheries resources. It is projected that over the next ten years, fishmeal inclusion in diets for carnivororous species will be reduced by 10–30 percent and replaced by cost-effective alternatives to fishmeal (Rana *et al.*, 2009; Tacon *et al.*, 2011). Further, with increased feed efficiency and better feed management, feed conversion ratios for many aquaculture species will be improved.

Although the current discussion about the use of marine products as aquafeed ingredients focuses on fishmeal and fish oil resources, the sustainability of the aquaculture sector is more likely to be more linked with the sustained supply of terrestrial feed ingredients of animal and plant origin. Soybean meal is currently the most common source of plant proteins used in compound aquafeeds. Other plant proteins deriving from pulses, oilseed meals, corn products and other cereals are also being increasingly used.

If the aquaculture sector is to maintain its current average growth rate of 8 to 10 percent per year to 2025, the supply of nutrient and feed inputs will have to grow at a similar rate. There are needs for major producing countries to place particular emphasis to maximize the use of locally available feed-grade ingredient sources, particularly nutritionally sound and safe feed ingredients whose production and growth can keep pace with the growth of the aquaculture sector.

Aquaculturists are optimistic that far more fish can be produced, but there are issues of nutritional quality using land-based feeds, particularly regarding alternatives to fish oil. Long chained (LC) omega-3 fatty acids are mainly found in fish oil, so fish oil is an essential feed ingredient in order to assure the nutritional quality of the end product. Intensive research is therefore required in order to find alternatives to fish oil, such as LC omega-3 production from hydrocarbons by yeast fermentation, extraction from algal sources and/or genetic modification of plants to become LC omega-3 fatty acids producers. However, for now and probably for the new decade, the source of LC omega-3 fats will remain marine capture fisheries.

Trade and marketing

The share of fishery and aquaculture production (live weight equivalent) entering international trade as various food and feed products increased from 25 percent in 1976 to 39 percent in 2008, reflecting the sector's growing degree of openness to, and integration in, international trade. High-value species such as shrimp, prawns, salmon, tuna, groundfish, flatfish, seabass and seabream are highly traded, in particular as exports to more affluent economies, and low-value species such as small pelagics are also traded in large quantities. Products derived from aquaculture production are contributing an increasing share of total international trade in fishery commodities, with species such as shrimp, prawns, salmon, molluscs, tilapia, catfish, seabass and seabream (FAO, 2011a).

Aquaculture continues to be the fastest-growing animal-food-producing sector and to outpace population growth, with per capita supply from aquaculture increasing from 0.7 kg in 1970 to 7.8 kg in 2008, an average annual growth rate of 6.6 percent. At present, about 46 percent of world food fish supply comes from aquaculture, which compares to 32 percent some ten years ago.

The importance for biodiversity of this strong development of aquaculture is outstanding, as only a handful of species are commercially cultivated, while the world capture fisheries includes a huge range of species, some with very limited catch figures.

On the marketing side, the importance of supermarkets in the distribution of seafood is increasing. In some countries, both in the developed and the developing world, supermarkets account for more than 70–80 percent of seafood retailing. This process has emerged relatively quickly during the last decade. These retailers have certain characteristics which aim at standardized sizes, product quality and constant availability.

These requirements are easily met by the aquaculture industry, while capture fisheries has difficulties meeting these requests, as sizes and quality of capture fisheries, principally a hunting exercise, vary greatly. Thus further concentration of the supermarkets in seafood marketing will result in even more demand for aquaculture products, and thus in less variety of fish products available to the consumer. This will result, in the long run, in less biodiversity, as the few aquaculture species, salmon, shrimp, bivalves, tilapia and catfish, will increasingly replace the wild species traditionally living in the aquatic environment used for aquaculture production. Thus the increasing importance of aquaculture has a negative impact on biodiversity, but might be the most sustainable option of meeting the increasing demand of aquatic foods.

Biosecurity and biodiversity

The current trend towards globalization of the aquaculture industry, while creating new market opportunities for aquaculture, has also resulted in intensified production, increased pressure to improve production performance and the widespread movement of aquatic animals. This scenario has increased the likelihood of disease problems occurring. Transboundary aquatic animal diseases (TAADs) are highly infectious with strong potential for very rapid spread irrespective of national borders. They are limiting the development and sustainability of the sector through direct losses, increased operating costs, closure of aquaculture operations, unemployment; and indirectly, through restrictions on trade and potential negative impacts on biodiversity (Bondad-Reantaso *et al.*, 2005).

Biosecurity is a strategic and integrated approach that encompasses both policy and regulatory frameworks aimed at analysing and managing risks relevant to human, animal and plant life and health, including associated environmental risks (FAO, 2007). It covers food safety, zoonoses, introduction of animal and plant diseases and pests, introduction and release of living modified organisms (LMOs) and their products (e.g. genetically modified organisms or GMOs), and the introduction of invasive alien species.

Effective biosecurity frameworks and aquatic animal health management strategies are important for safeguarding animal health, enhancing food safety, promoting environmental sustainability and protecting biodiversity. They play an important role at every stage of the life cycle of an aquatic animal from hatching to harvesting and processing, and thus are essential to ensuring sustainable and healthy aquatic production. They can also stimulate increased market supply and private investments, as such frameworks support farmers' ability for efficient production of healthy products that are highly competitive in the market, thus increasing their incomes, improving their resilience and enabling them to effectively respond to the impacts of production risks.

While significant developments have taken place in many countries with regard to managing aquatic animal health, the current trend towards intensification, expansion and diversification of aquatic food production continues to present many challenges. Countries should consistently carry out effective biosecurity measures at both farm and policy levels to: reduce the risks from emerging threats brought about by expanding species for aquaculture and improving production efficiency; prevent, control and eliminate diseases in a timely manner; and respond to consumers' increasing concerns for healthy and nutritious aquatic production, food safety, ecosystems integrity and animal welfare.

Ecosystem approach

Many rural households depend heavily on aquatic ecosystems as a source of essential nutrients in their food supply. Rapidly growing populations and changes in agronomic practices have however often resulted in increased use of pesticides and fertilizers in agricultural activities in order to produce more food in less space. This development is in many cases threatening the food and nutrition security of populations, as biodiversity might be reduced in ecosystems affected by intensive agriculture, such as rice cultivation. Traditional cultivation of rice crops under flooded conditions provides an excellent environment for aquatic organisms such as fish (Halwart, 2007). Intensive rice farming has increased production and reduced the price of this essential commodity, but at the same time the aquatic biodiversity in the rice fields is inevitably being reduced. Poor populations, who traditionally obtained a significant part of their dietary diversity from this aquatic environment, are threatened. The aquatic ecosystem, such as rice fields, have been reported to provide more than 100 aquatic species such as fish, molluscs, reptiles, insects, crustaceans, and plants in Cambodia (Balzer *et al.*, 2005), many of which are collected and utilized on a daily basis by rural households (Halwart and Bartley, 2007). These species are excellent sources of essential nutrients, such as proteins, essential fatty acids, vitamin A, calcium, iron, zinc and other micronutrients, deficient in many diets (James, 2006).

International frameworks

In order to secure a sustainable use of aquatic resources, it has been important to identify rights and responsibilities of states who manage fisheries resources. In the mid-1970s, exclusive economic zones (EEZs) were widely introduced, and in 1982 the United Nations Convention on the Law of the Sea provided a new framework for the better management of marine resources. Growing population and increasing demand for fish and fishery products has increased investments in fishing fleets and processing facilities, leading to a rapid and uncontrolled exploitation of limited fishery resources. In order to address the concerns related to responsible and sustainable fisheries, FAO was requested to prepare an international Code of Conduct for Responsible Fisheries (FAO, 1995).

The Code was finally adopted in 1995 by the FAO Conference, and provides a framework for national and international efforts to ensure sustainable exploitation of aquatic living resources in harmony with the environment. The Code of Conduct for Responsible Fisheries establishes principles and standards applicable to tile conservation, management and development of all fisheries, in a non-mandatory manner.

The Code of Conduct for Responsible Fisheries has been used by many governments as a basis to introduce policies and mechanisms in order to ensure the sustainability and the biodiversity of their fish stocks and aquatic environment. FAO has also developed voluntary guidelines in order to help member countries, such as the "FAO International Guidelines for the Management of Deep-sea Fisheries in the High Sea" (FAO, 2008), a unique international instrument promoting responsible fisheries while ensuring the conservation of marine living resources and the protection of marine biodiversity.

The increased focus on sustainability by governments and environmental organizations such as the World Wide Fund for Nature (WWF) has increased the awareness among consumers of how the limited natural resources are utilized and how it may impact the environment and biodiversity. As a result, the private sector has introduced initiatives to meet the demand from consumers, such as eco-labels, insuring responsible fishing practices and sustainable use of the aquatic environments.

The Marine Stewardship Council (MSC) has one of the best known standards and certification programmes for the fisheries sector, but many other eco-labelling schemes such as "Friends of the Sea", "KRAV" and "Naturland" provide their service to the fisheries and aquaculture sector (Blaha, 2011). On the request from member states, FAO has produced guidelines in order to harmonize the increasing number of certification schemes, such as the "FAO Guidelines for the Eco-Labelling of Fish and Fisheries Products from Marine Capture" (FAO, 2005), and the "Guidelines for Aquaculture Certification" (FAO, 2011b).

With regard to the international trade in aquatic animals, different obligatory international treaties/agreements and other voluntary guidelines are involved. Examples of binding international agreements include the following: Sanitary and Phytosanitary Agreement of the World Trade Organization, SPS Agreement (WTO, 1994), the Convention on Biological Diversity (CBD, 1992), the Convention on International Trade of Endangered Species and European Union related legislation and directives. Examples of voluntary agreements/guidelines include that of the International Council for the Exploration of the Seas (ICES, 2005), the codes of practice of the European Inland Fisheries Advisory Commission (Turner, 1998) and a number of FAO guidelines. In many instances, voluntary international guidelines are incorporated into national legislations and thus become mandatory at the national level.

References

Balzer, T., Balzer P. and S. Pon 2005. Traditional use and availability of aquatic biodiversity in rice-based ecosystems. In: Halwart, M. and D. Bartley (eds.) Aquatic biodiversity in rice-based ecosystems. Studies and reports from Cambodia, China, Lao PDR and Vietnam. [CD-ROM]. Rome: FAO. Also available at ftp://ftp.fao.org/FI/CDrom/AqBiodCD20Jul2005/Start.pdf

Blaha, F. (2011). EU Market Access and Eco-Labbeling for Fishery and Aquaculture Products. Swiss Import Promotion Programme. Zurich, SIPPO. 48p.

Bondad-Reantaso, M.G., Subasinghe, R.P., Arthur, J.R., Ogawa, K., Chinabut, S., Adlard, R., Tan, Z. & Shariff, M (2005). Disease and health management in Asian aquaculture. Veterinary Parasitology, 132, 249–272.

Convention on Biological Diversity (CBD) (1992). Convention on Biological Diversity. Available at www.cbd.int/

FAO (1995). Code of Conduct for Responsible Fisheries, Rome, FAO. 41p.

FAO (2005). Guidelines for the Eco-Labeling of Fish and Fisheries Products from Marine Capture.

FAO (2007). FAO Biosecurity Toolkit. Food and Agriculture Organization of the United Nations. Rome, FAO. 128p.

FAO (2008). FAO International Guidelines for the Management of Deep-sea Fisheries in the High Sea. Rome, FAO.

FAO (2010). Fishstat Plus: universal software for fishery statistical time series. Aquaculture production: quantities 1950–2008; Aquaculture production: values 1984–2008; Capture production: 1950–2008; Commodities production and trade: 1950–2008; Total production: 1970–2008, Vers. 2.30. FAO Fisheries Department, Fishery Information, Data and Statistics Unit. Available at www.fao.org/fi/statist/FISOFT/FISHPLUS.asp

FAO (2011a). The State of World Fisheries and Aquaculture 2010, FAO Fisheries and Aquaculture Department. Rome, FAO.218p. Available at www.fao.org/docrep/013/i1820e/i1820e00.htm

FAO (2011b). Guidelines for Aquaculture Certification. Rome, FAO. 26p. Available at: ftp://ftp.fao.org/FI/DOCUMENT/aquaculture/TGAC/guidelines/Aquaculture%20Certification%20GuidelinesAfterCOFI4-03-11_E.pdf

FAO/WHO (2011). Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption. Rome, FAO. (in press).
Halwart, M. (2006). Biodiversity and nutrition in rice-based aquatic ecosystems. Journal of Food Composition and Analysis, 19, 747-751.

Halwart, M. and Bartley, D. 2007. Aquatic biodiversity in rice-based ecosystems, pp. 181-199. In: Jarvis, D.I., Padoch, C. and Cooper, H.D. (Eds.) Managing biodiversity in agricultural ecosystems. Columbia University Press. 492p.

International Council for the Exploration of the Seas (ICES) (2005). ICES Code of practice for the introductions and transfers of marine organisms. Copenhagen, International Council for the Exploration of the Sea. 30p.

James, D. (2006). The impact of aquatic biodiversity on the nutrition of rice farming households in the Mekong Basin: Consumption and composition of aquatic resources. Journal of Food Composition and Analysis, 19, 756-757.

Lewin G.A., Schachter H.M., Yuen D., Merchant P., Mamaladze V., Tsertsvadze A. (2005). Effects of omega-3 fatty acids on child and maternal health Agency for Healthcare Research and Quality (AHRQ). Evid Rep Technol Assess (Summ), 1-11.

Martinez M. (1992). Tissue levels of polyunsaturated fatty acids during early human development. J Pediatr; 120:S129-38.

Mozaffarian D., Rimm E.B. (2006). Fish intake, contaminants, and human health: evaluating the risks and the benefits. JAMA, 296, 1885-99.

Rana, K.J., Siriwardena, S. and Hasan, M.R. (2009). Impact of rising feed prices on aquafeeds and aquaculture production. FAO Fisheries and Aquaculture Technical Paper, No. 541, 63 pp.

Tacon, A.G.J., Hasan, M.R. and Metian, M. 2011. Demand and supply of feed ingredients for farmed fish and crustaceans: trends and future prospects. FAO Fisheries and Aquaculture Technical Paper, No. 564. FAO (in press)

Turner, G. (ed.) (1988). Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms. EIFAC Occasional Paper, No. 23. European Inland Fisheries Advisory Commission. Rome, FAO.

World Trade Organization (WTO) (1994). Agreement on the Application of Sanitary and Phytosanitary Measures. p. 69–84. In The results of the Uruguay Round of multilateral trade negotiations: the legal texts, General Agreement on Tariff and Trade (GATT), World Trade Organization, Geneva.

DIETARY BEHAVIOURS AND PRACTICES: DETERMINANTS, ACTION, OUTCOMES

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Abstract
This study review summarizes the results of a scientific expertise which was commissioned by the French Ministry of Agriculture in 2010. It aims to define the typologies of food behaviours and their changes in time, to establish the state of the art on the determinants of these behaviours and their impact on health and finally to examine the numerous public or private actions or campaigns aiming to improve these behaviours and to conclude on their effects.

1. Introduction: Context and objectives of the collective scientific expertise

This paper reports the main conclusions of a Collective Scientific Expertise (CoSE) commissioned by the French Ministry of Food, Agriculture and Fisheries and conducted by INRA (French National Agriculture Research Institute) from May 2010 until June 2011. Research into the links between diet and maintaining good health has gradually widened in scope, from research into the relationship between nutrients and health (e.g. the role of vitamins), to the complex nutritional effects of food – thus recommending the consumption of certain foods containing more valuable nutrients (e.g. fruit and vegetables, less saturated fatty acids) – and how best to combine foods within diet. For several years, public policies based on these findings have led to initiatives aiming to render diet more beneficial to health (nutritional information campaigns, concerted action with the food industry). But the growing number of overweight people shows that this action has fallen short of its objective. In order to make these public policies more effective, it is important to know better how consumers make their food choices and which are their determinants. How are these affected by food composition, hunger, level of education, income, advertising, accessibility and so on, depending on the consumer's age. These issues led the French Ministry of Food, Agriculture and Fisheries to commission INRA to undertake a collective scientific expertise, and thus to obtain an updated state of published scientific knowledge on these different determinants for use in guiding policy-makers.
Dietary behaviours are formed by considerations that are not all connected with food and nutrition per se. Investigating these behaviours means making the connection between all the relevant disciplines – epidemiology, nutrition, food science, psychology, sociology, economics – in order to grasp how behaviours are formed, and how levers can be used to modify them so that they are in line with nutritional guidelines.

2. CoSE methods and scope

The CoSE is based on certified international scientific articles, which guarantees reliability of the information used. A group of about 20 scientific experts working for various scientific institutions in France (INRA, Institut Pasteur in Lille, University Hospital in Lille, CIHEAM, CNRS) were involved in this CoSE. Their expertise covered areas as diverse as epidemiology, physiology, food sciences, economics, sociology, marketing and psychology. Their work drew upon a total of about 1 840 articles, 93 percent of which were scientific, in addition to statistical data, books and technical reports. The experts selected all the relevant facts in these documents, then analysed and assembled them to provide insight into the issues in hand.
The CoSE gives neither opinions nor recommendations. It presents a thorough review of the knowledge available on the determinants of dietary behaviour, using a multidisciplinary approach combining the life sciences with the human and social sciences. It also outlines some prospective measures, based on an evaluation of a number of public or private initiatives. It examines human dietary behaviour overall and refers neither to pathologies and eating disorders requiring medical treatment (malnutrition, bulimia, anorexia, etc.) nor to specific eating practices (vegetarianism,

diets prescribed by religious belief etc.), nor does it study the relationship between diet and physical exercise, recently investigated by Inserm.

3. Main results of the expertise

3.1 An overall approach to diet is required

Changes in dietary practices over the past few decades, particularly the increase in the proportion of fat in diet, are linked with modifications in food supply (technological innovation, food chain) and more generally with changes in lifestyle.

Research on the relationship between diet and health focused primarily on the role of nutrient intake (lipids, vitamins) or individual foodstuff intake (fruit, vegetables, meat). This research, often experimental, has confirmed certain hypotheses linking food consumption to effects on metabolism which can be good or bad for health. Extrapolation of these findings, obtained in controlled trials, to real life requires the integration of other aspects (living conditions, income).

Certain epidemiological studies, after examining different diets, have established a number of typologies that are more representative for studying real dietary behaviour.

Although correlations between diet typologies and health are clear, it is difficult to establish causalities between changing dietary practices and certain chronic illnesses (cancer, cardiovascular disease). Links are more clearly established for obesity.

3.2 The physiological mechanisms regulating food intake are affected by environment

Physiological regulation of food intake is based on the alternate cycle of two physiological states: hunger and satiety. A network of internal signals, coming from the digestive tract and from the central nervous system, alternates food intake with satiety. This mechanism allows self-regulation of energy intake, and is particularly effective in young children. This regulatory system seems to have altered in obese people.

Energy compensation can take place between one meal and the next, in the case of temporary deficiency or excess. However, dietary deficiencies are compensated far more easily than dietary excess managed. In a society with plenty of choice, temporary overeating is thus more likely to be poorly managed during the following meals, leading to weight gain.

Intake is adjusted more effectively by eaters who are attentive to the physiological signals of hunger and fullness, and who are more careful about what they eat. Distractions (e.g. eating in front of the TV, in a noisy place, with stress) increase the quantity ingested during the meal and upset the energy compensation process from one meal to the next.

Nutritional composition and food consistency determine the satiation capacity of food. This means that these characteristics can be used for limiting the consumption of foods not affected by physiological regulation (e.g. soft drinks).

Eating triggers a sensation of enjoyment by activating a physiological system in the brain called the reward circuit. This eating enjoyment is accentuated by palatable foods (nice taste) which are more often than not fatty or sweet high energy-dense foods. Enjoyment of sweet foods has been observed from birth. In obese animals and humans, recent findings have shown that addictive-type mechanisms can develop for sweet foods.

Social norms and attitudes, which vary according to age group, personal experience, and social and cultural backgrounds, shape and set dietary behaviours for time schedules, family meals, and table manners. These social conventions can affect physiological regulation.

3.3 Generic nutritional information and prevention campaigns have little short-term impact on behaviour when used alone

Nationwide information campaigns reach first and foremost the social groups already aware of the link between diet and health. These messages could thus increase behavioural disparities in the short term. For the same reasons, nutritional labelling has little impact, and is used mostly by educated or nutrition-conscious people. The technical information that is marked on labels is rarely used by consumers, who are not always able to take advantage of it and whose attitudes concerning food fall into simple categories: good or bad, healthy or unhealthy.

Awareness of nutritional messages and their application do not generally lead immediately to the desired changes in behaviour. Over a longer time scale, changes in the behaviour of the wealthy, induced by preventive campaigns, may filter down into other strata of society through adoption of the culturally more appealing model.

3.4 Dietary behaviour can be affected by information strategies combining different tools and targeting individuals or specific groups

How information is communicated is crucial. Nutritional information is more effective in the short-term when it is part of a specific campaign targeting an individual or a cohesive group. Therapeutic education – the cognitive-behavioural approach used with obese patients or people suffering from dietary behaviour disorders – and social marketing – which aims to make microchanges in the individual's environment – have shown that the "small steps" strategy can cause apparently minor modifications to behaviour that accumulate and last longer. The success of these initiatives depends on how supportive the family, local contacts and social groups are.

Precisely-targeted strategies are costly, hence the advantage of combining them with more general and cheaper prevention initiatives. Costs can also be lowered by using the diverse and widespread means of communication currently available, some of which allow information to be accessed by the individual.

3.5 The consumer is subjected to different environmental stimuli, which can bias opinion

Food availability and composition are more effective levers on action than prices. According to economic theory, the consumer reigns over a market which must cope with his or her nutritional needs, hedonistic preferences and health concerns. Nutritional prevention policies are thus focused on the consumer (even risking guilt about food choices). However, recent findings that call on both economics and marketing have shown that consumer opinions can be distorted by errors of perception and environmental stimuli. Thus, policies have greater impact when they also affect food supply, and purchasing and eating contexts: availability, food composition.

Altering the nutritional and energy quality of foods (through regulations, or incentives such as nutritional improvement charters and public/private agreements) entails adjustments to certain food components that are deemed detrimental or beneficial to health (salt, type of fatty acids etc.) and improves the satiation properties of food (added fibre, lower energy density).

Playing on food availability can have an immediate impact: the presence of fruit baskets instead of snack machines has proved effective in school experiments. In the United States, proximity of fast-food restaurants (particularly near schools) is known to lead to overeating.

Food packaging size and clearly marked nutritional claims can lead to underestimation of quantity (visual bias) and/or energy content of foods or dishes.

Economic simulations tend to show that taxes or subsidies are not always effective levers in the short term. For a significant drop in the consumption of foods reputed to be bad for health (usually high-energy products), the tax needs to be high (threshold effect), which would penalize the consumers who have no choice but to buy these inexpensive products. These interventions on supply can also have undesirable effects: lower nutritional quality of ingredients used, move towards budget products etc.

3.6 Childhood and old age are more favourable to modifications in dietary behaviour

3.6.1 Childhood

Although dietary behaviour alters with age, sensory preferences are set during early childhood and are difficult to change thereafter. Sensory learning forms taste and food spectrum, and these are shaped before birth from the seventh month of pregnancy. New research themes are currently investigating the impact of perinatal nutrition which, according to animal experiments, causes lasting metabolic imprinting and which can sometimes be passed down. Repeatedly offering a variety of foods without forcing the child seems to be the best way of widening food acceptance. School not only provides tasting opportunities, but could also improve awareness of hunger, fullness and satiety.

Preventive action has proved effective for mothers whose children risk being overweight, particularly by changing the mothers' attitudes regarding their traditional responsibility for nourishment. Child obesity-control programmes increasingly call for parental learning.

Dietary habits change during adolescence, and meals eaten outside the home offer opportunities to experience a certain freedom (meal times, meal composition). These practices do however appear to be temporary, and a return to a family type of diet is observed when couple relationships form, when children are born, or when young people start working. So, except for dietary disorders (anorexia, bulimia, not dealt with here) and risky practices (binge drinking), the diet of adolescents is not a public health problem. If difficulties with dietary behaviour are experienced during childhood, this phenomenon can be accentuated upon adolescence with negative consequences for well-being and health.

3.6.2 Old age

During old age, dietary behaviour can become more unstable. Retirement, death of a spouse, solitude, deteriorating health and less autonomy often have negative repercussions on dietary practices and food intake. A considerable proportion of elderly people suffer from malnutrition, which is recognized as a public health risk factor.

A positive point is that elderly people are attentive to preventive messages concerning health. Carers and the immediate social circle of elderly people are crucial for maintaining good dietary practices and/or implementing nutritional preventive strategies.

It should be noted that dietary behaviour could be linked to one's generation. This hypothesis, suggested by CREDOC findings using the Budgets survey, needs to be scientifically supported. The most striking fact is that the more recent generation spend three times less money to buy fresh fruits than the generation born between 1937 and 1946.

3.7 The underprivileged are less receptive to preventive messages

Dietary inequalities have continued into recent years. Food can absorb up to 50 percent of the budget of the more underprivileged households in France, while this figure stands at 15 percent for the population overall.

Underprivileged people, poor and/or undereducated, suffer more from obesity.

Their diet deviates from nutritional guidelines more than that of wealthier populations. A greater number of risk factors are associated with their dietary practices: sedentary lifestyle, distraction linked to TV viewing, low self-esteem. The preventive messages for nutrition and health are less well understood and can even make them feel at fault, given that these messages are on a completely different wavelength to the attitudes they have about diet, health or body norms. They also need to cope with other worries which appear more important to them. The desire to buy foods that are promoted by intense advertising (high-energy-dense foods) undermines their efforts to conform to guidelines.

4. Research needs

If detailed typologies of French consumer behaviours are to be established, large pooled longitudinal cohorts need to be recruited and which are representative of the entire population. Tools need to be validated for collecting and using reliable data. If these methods were extended to other countries, the specificities of the French dietary model would stand out.

The causalities between diet and health can be determined in two ways: firstly by using the systems approach to integrate all the fragmentary knowledge available about how nutrients affect physiological systems; and secondly, by combining epidemiological studies with systematic phenotyping and genotyping of individuals in the cohorts (requiring a biological sample bank). This second approach would need to include detailed analysis of gut flora, since its role appears to be increasingly important.

Changes in food supply (product quality, price, availability) can have major unintentional effects on dietary behaviour, necessitating further research (effects on market segmentation, market competition, consumer preferences).

Consumer behaviour models need to account for the relative weight of each determinant, particularly the effects of social environment and spatial factors on individual diet. One priority consists of combining economic mechanism models, with models of the biological systems involved in the connections between diet and health.

Another priority will be to explain through brain imaging techniques how the different signals leading to purchasing choices function. Also, how signals of fullness and satiety are related with food and meal characteristics (such as the role of sugar on the activation of reward pathways) and meal context (particularly conversation and distraction).

Research into the evaluation of public policies needs to be organized and extended. The ambivalent outcomes of these policies (mostly positive but potentially a source of growing inequalities, such as for price policies) should be specifically addressed using cost-benefit analyses, up to and including estimation of the social costs of saved lives. The reasons for the difference in impact between product marketing tactics and information campaigns remain to be explored.

References

"Dietary behaviours and practices. Determinants, Action, Outcomes" Collective Scientific Expertise. P. Etiévant, F. Bellisle, J. Dallongeville, C. Donnars, F. Etilé, E. Guichard, M. Padilla, M. Romon-Rousseaux, C. Sabbagh, A. Tibi (editors) 2010, INRA publisher (Paris), 280 pages.

The full report and and an executive summary (63 pages) can be accessed at the following site:
http://www.inra.fr/l_institut/expertise/expertises_realisees.

CONSERVATION OF PLANT DIVERSITY FOR SUSTAINABLE DIETS

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Abstract
Biologically diverse diets are more likely to be nutritionally replete, and contain intrinsic protective factors. An increasing number of initiatives promote dietary diversity for improved child nutrition and protection against chronic diseases. The agricultural biodiversity central to diverse diets, including many lesser-known and underutilized plant species, has developed over millennia through biocultural evolution of the plant genome and associated cultural codes. However, the biocultural diversity of food plants is under threat from changing eating patterns, intensive agriculture, and climate change, resulting in a loss of local food plant diversity from diets and threatening food and nutrition security. We recommend a holistic approach promoting the use of traditional food plant diversity together with conservation of genetic material and associated traditional knowledge.

1. Introduction

Traditional diets, containing a high proportion of lesser known and underutilized plant species, are rich in biodiversity. They are an ideal basis for sustainable diets and for chronic disease prevention. Traditional diets are under threat in developing countries due to anthropogenic factors. Addressing such threats requires a holistic approach, where complementary *in situ* and *ex situ* techniques combine to conserve local agricultural biodiversity and the knowledge on how to use it. Here we explore two projects that have attempted to do this, and make recommendations on best steps forward.

2. Dietary diversity, agricultural biodiversity and biocultural evolution

Agricultural biodiversity is broadly defined by the Convention on Biological Diversity as those "components of biological diversity of relevance to food and agriculture" and includes crops and "wild plants harvested and managed for food" (CBD, 2000). Agricultural biodiversity and dietary diversity form the basis of human health and are intrinsically linked through traditional food systems and food habits. Consuming a high level of dietary diversity is one of the most longstanding and universally accepted recommendations for human health at national, regional and international levels (WHO (Europe), 2003; UK Food Standards Agency, 2009). It has been recommended that we should "eat at least 20, and probably as many as 30 biologically distinct types of food, with the emphasis on plant food [with a week as a time frame]" (Wahlqvist *et al.,* 1989; Savige, 2002). Dietary diversity across as many food groups as possible ensures dietary adequacy, increased food security, a reduced intake of toxicants and protection against chronic diseases (Slattery *et al.*, 1997; Hatløy *et al.*, 1998; McCullough *et al.*, 2002; Wisemann *et al.*, 2006).

Dietary diversity is underpinned by agricultural biodiversity. Although just 12 plant species contribute 80 percent of total dietary intake (Grivetti and Ogle, 2000), many more lesser-known, underutilized, semi-domesticated and wild plants are harvested and managed for food. The figure of more than 7 000 is commonly cited (Bharucha and Pretty, 2010), but the total number of plant species that have been grown or collected for food may be as high as 12 600. Agricultural biodiversity is selected and managed by farmers – even non-cultivated plant species are managed to a greater or lesser degree by the people who know their uses, harvest them, and allow their continued survival – and the CBD recognizes "traditional and local knowledge" as an important dimension of agricultural biodiversity (CBD, 2000).

In a globalized world of intensive agriculture and agribusiness, it is easy to forget that our food systems are the result of thousands of years of synergistic interaction between biological and cultural resources or, as one author puts it, "biocultural evolution" (Katz, 1987). The nutritional adaptation described by Ulijaszek and Strickland (1993) shows how, during the process of biocultural evolution, genetic codes are stored in the DNA of plants and cultural codes in the cultural beliefs and practices of people using them. This coded information interacts with the environment through plant physiology and human behaviour and leads, ultimately, to the end state of plant phytochemistry (nutritional value and toxicology) and human nutritional and health status

Evolution	Codes		Strategies		States
Plants	DNA	+	Physiology	▶	Phytochemistry
People	Culture	+	Behavior	▶	Nutritional Status

Figure 1. Nutritional adaptation and biocultural evolution.

When these mechanisms interact with one another in a positive manner, there is a distinct biocultural advantage. Nowhere is this more apparent than in the use of maize. In the Americas, maize flour is usually limed prior to making tortillas. Magnesium and calcium salts are added, releasing niacin which enhances the quality of protein. Phytate is neutralized, making iron and zinc bioavailable (Katz *et al.*, 1974). African cultures, who do not lime their maize flour, are at a biocultural disadvantage. For example, Kuito, an area in Angola where maize forms a large proportion of the diet, is an area of endemic niacin deficiency (Golden, 2002).

3. The loss of biocultural diversity and dietary diversity

The close relationship between agricultural biodiversity, cultural diversity and dietary diversity is no more apparent than in farming communities in developing countries. However, over the last century there has been a loss of agricultural biodiversity and associated traditional knowledge, particularly for food plants, with a corresponding reduction in dietary diversity. Many attribute these losses to intensive agriculture, the nutrition transition and environmental pressures such as climate change (Goodland, 1997; Johns and Eyzaguirre, 2006; Purvis *et al.*, 2009). Since the green revolution, a focus on providing high energy and high protein foods of plant origin to an expanding global population has been the main driver of intensive agriculture. While succeeding in this, it has pushed lesser known agricultural biodiversity into kitchen gardens, fallow fields and field margins, communal land, grasslands, orchards, and roadsides, at risk from agricultural expansion, road widening, hedgerow removal, overgrazing, overharvesting, herbicides and other non-traditional agronomic practices. Climate change is likely to become an increasingly significant threat, particularly for narrowly adapted endemic species (Millennium Ecosystem Assessment, 2005; Jarvis *et al.*, 2010).

The nutrition transition is also playing its part, as the desire for "modern" westernized diets causes a shift from diverse traditional diets, relatively low in energy and high in plant diversity, to modern diets, high in energy and low in plant diversity. The stigma often associated with traditional diets not only supports and encourages the intensification of agriculture, but also exacerbates the trend towards a global obesity epidemic.

Although the main focus of global agricultural research remains the provision of calories and plant protein, pressures on our current global food system mean that the intensive agricultural practices developed over the last century may not be sustainable in the future, leading many to advocate the use of lesser known or underutilized plants from traditional food systems as part of the solution (Johns and Eyzaguirre, 2006; Bharucha and Pretty, 2010). Conserving such plants, and the cultural diversity that supports them, requires a holistic approach, based on an understanding of plant and human interactions.

4. The conservation of food plant diversity

The CBD cross-cutting initiative on biodiversity for food and nutrition includes an operational objective to conserve and promote the wider use of biodiversity for food and nutrition. *In situ* conservation and sustainable use of food plant diversity, including the dietary-diversity based interventions described in this volume, is the preferred option and is advantageous for several reasons: 1) it is readily available to local people to use; 2) both the genetic and cultural diversity is conserved; 3) biocultural evolution of the food system can continue, adapting to local needs over time and 4) users have a high level of control over their food resources.

4.1 Case study of community conservation – TATRO Women's Group in Western Kenya

TATRO Women's Group is based in the Western Province of Kenya, in the Yala Division of Kiswero District. Since 1993, they have worked with local, national and international agricultural research organizations, directly impacting nearly 500 families. In 2005, in collaboration with the National Museums of Kenya, and the Royal Botanic Gardens, Kew, they undertook a needs assessment for the conservation of traditional food plants (Nyamwamu *et al.*, 2005). The study revealed that three food plant species, Osae, Obuchieni and Onunga (*Aframomum angustifolium* (Sonn.) K.Schum., *Tristemma mauritianum* J.F.Gmel. and *Rubus apetalus* Poir.) had been lost from the area in recent years. A further 50 food plants, and the knowledge on how to use them, were only known by community elders. Harvesting of traditional food plants had decreased on cultivated and uncultivated land, and food preferences and cash cropping were driving an increase in the cultivation of exotic cereals and pulses. In addition, wild fruits such as Ojuelo (*Vitex doniana* Sweet) were once plentiful but were becoming harder to find as more land came under cultivation. These findings were unexpected, particularly to TATRO members. In response, they compiled a list of community experts, and organized activities for the sharing of seeds and traditional knowledge of "at risk" food plants. Current activities, focused on a community resource centre in Yala Village, include the promotion of growing traditional food plants in kitchen gardens, on communal land and integrating their use in school feeding projects, together with outreach work in Western Nyanza.

Despite such efforts, conservation-through-use may not be enough to adequately protect wild food plants for the sustainable diets of the future. With slow-onset climate change exacerbating other threats, "*in situ* diversity needs to be collected before it disappears" (FAO, 2011a).

Ex situ seed banking can complement such community-based activities, and has several advantages: 1) a wide range of genetic diversity is conserved; 2) well maintained seed banks can conserve seeds for decades or hundreds of years; 3) seed banks can support reintroduction of food plants to areas where they have been lost; 4) seed bank collections, supported by herbarium specimens, provide a verified source of material for screening for genetic diversity in nutritional properties and other desirable traits; 5) germination protocols developed by seed banks are a useful starting point for projects wishing to promote the use of lesser known and underutilized food plants.

The use of seed banking, as a means of conserving, and making available the genetic diversity of food plants is well established. International centres around the world have global mandates for the conservation of the major food crop species. Although FAO (2010) reports "a growing interest in collecting and conserving minor, neglected and underutilized crops" few wild food plants are conserved in seed banks. Of the global germplasm holdings for which the type of accession – advanced cultivar, breeding line, landrace, wild species – is known, only 10 percent are wild species, most of them industrial and ornamental or forage species (FAO, 2010).

4.2 Case study of Seed Banking – The Millennium Seed Bank Partnership (MSBP)

The MSBP is the world's largest initiative to collect, conserve and promote the use of wild plant species, involving major collaborations with 18 countries around the world, and less formal collaborations with 123 institutions in 54 countries. The Millennium Seed Bank (MSB) currently holds accessions of more than 28 000 species, including more than 10 379 accessions of 3 318 species with known food use.

The MSBP is working to overcome constraints to the conservation and use of plants important to local livelihoods. Germination tests have been carried out on 3 028 taxa with food uses; 2 102 of these have → 75 percent germination, the current minimum MSB standard for storage. Germination protocols are made available via the Seed Information Database (Royal Botanic Gardens Kew, 2008). Kew's "Difficult" Seeds project worked with African gene banks to identify 220 species, most of them food plants, with inherent seed storage problems, seed dormancy issues, or poor viability due to inadequate handling and storage. Training workshops included a two-day mini-workshop for local farmers and community representatives, with the aim of supporting and facilitating gene banks to engage with farmers. Essential seed biology information for 160 "difficult" species, together with training materials, is available via Kew's web pages (Royal Botanic Gardens Kew, 2010).

MSBP partners are also working with local communities to document, collect, conserve and propagate the genetic diversity of useful wild plants. The MGU-Useful Plants Project works with communities in Mexico, Mali, Kenya, Botswana and South Africa to identify the species that communities find most useful. Residents of Tsetseng, in the central Kalahari region of Botswana, are undertaking trial cultivation of *Citrullus lanatus* (Thunb.) Matsum. and Nakai and *Schinziophyton rautanenii* (Schinz) Radcl.-Sm in community gardens. In Mexico, MSBP partners UNAM have identified 339 species used for food in the Tehuacán–Cuicatlán Valley (Lira *et al.*, 2009) and are working on the propagation of species such as *Stenocereus stellatus* (Pfeiff.) Riccob. In Tharaka, Kenya, 76 food plants prioritized by local communities have been collected and conserved at the Gene Bank of Kenya and duplicated at the MSB. Associated ethnobotanical data was collected via a multistage process, including a pilot survey, questionnaire, guided group discussions, interviews, transects walks, observations and photography (Martin, 1995). This information has been shared with participating communities via brochures and posters, on-farm workshops and open days, community tree planting days, the sponsorship of farmers to share information during key cultural and medicinal day events in Kenya's Eastern Province, and the publication of a farmer's guide to seed collection, propagation and cultivation (Muthoka *et al.*, 2010).

5. Discussion

Seed collections of traditional food plants are of limited value without the associated knowledge of how to grow the plants and/or prepare the food product(s). Likewise, traditional knowledge is of little use if a community no longer has any seeds or plants of a particular species. *Ex situ* gene banks should seek ways to work with ethnobotanists and other social scientists to complement community based efforts to conserve traditional food plants. Hawtin (2011) suggests that the more poorly resourced national gene banks should focus their efforts on meeting local needs, rather than attempting to undertake the whole range of sometimes costly gene bank activities. Meeting local needs would mean the maintenance and distribution of materials of immediate interest, including locally important species. Crucially, materials would be distributed to farmers, as well as local breeders. Currently, local community groups may find it difficult to get access to national (and regional/state) seed collections (Swiderska, IIED, personal comment).

Hawtin (2011) also suggests that "conserving indigenous knowledge" should be a focus for national gene banks. This will be a challenge. Many gene banks document only broad categories of plant use – food, medicine, fuel – partly through lack of time and resources but also perhaps through fear of "biopiracy" accusations. Guarino and Friis-Hansen (1995) present a model for a participatory approach to documenting associated knowledge and Engels *et al*. (2011) discuss the ethical questions that must be addressed. Argumedo *et al*. (2011) argue that Indigenous Biocultural Heritage Territories (IBCHT), such as the "Potato Park" in Cuzco, Peru, offer a practical way of protecting plant genetic resources and associated knowledge systems. Based on the principle of Community Biodiversity Registers, traditional knowledge is documented in multimedia databases, helping to protect against any possible future patent applications from commercial organizations. More than 400 potato varieties have been repatriated from the International Potato Centre (CIP) to the Potato Park. Under the agreement, CIP has a responsibility to "provide technical assistance to the Park for the maintenance, monitoring and multiplication of seed and management of the repatriated genetic materials". The Potato Park could provide a model for gene banks and local communities to work together on the conservation of traditional food plant diversity. Community seed banks are often successful in conserving locally important species and varieties, but support is needed from extension services and national gene banks in order to scale up and have greater impact (Development Fund, 2011). The draft updated Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (FAO, 2011b) includes several objectives and research actions that could foster joint efforts to conserve and sustainably use nutritionally important wild and underutilized plant species.

6. Conclusions

- Lesser known and underutilized food plants will be needed to contribute to the sustainable diets of the future.
- The biocultural diversity of these food plants (plant genetic material and cultural knowledge associated with it) is required if the biocultural advantage and optimal nutritional value are to be gained from them.
- A holistic approach to conservation, which combines *in situ* and *ex situ* methods, is required.
- Combining these methods is difficult and requires the collaborative efforts of farmers, field workers, and scientists from the social and natural sciences.

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References

Argumedo, A., Swiderska, K., Pimbert, M., Song, Y. , Pant, R. (2011). Implementing Farmers Rights under the FAO International Treaty on PGRFA. Paper prepared for the Fourth Governing Body of the International Treaty on PGRFA, BALI 14-18 March 2011.

Bharucha, Z., Pretty, J. (2010). The roles and values of wild foods in agricultural systems. Philosophical Transactions of the Royal Society B: Biological Sciences 365:2913-26

CBD (2000) Agricultural biological diversity: review of phase 1 of the programme of work and adoption of a multi-year work programme. COP 5 Decision V/5.

Development Fund (2011). Banking for the Future: Savings, Security and Seeds. Oslo, Norway. http://www.utviklingsfondet.no/filestore/TEST_CSB_ferdigrapport.pdf_liten.pdf

Engels, J.M.M., Dempewolf, H., Henson-Apollonio, V. (2011). Ethical Considerations in Agro-biodiversity Research, Collecting and Use. J. Agric Environ Ethics 24,107–126.

FAO (2010). The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture. Rome: Food and Agriculture Organization of the United Nations.

FAO (2011a). Climate Change and Food Security in the Context of the Cancun Agreements. Submission by the Food and Agriculture Organization of the United Nations to the 14th session of the AWG‐LCA, in accordance with paragraph 1 of the Bali Action Plan.

FAO (2011b) Draft updated global plan of action for the conservation and sustainable utilization of plant genetic resources for food and agriculture. CGRFA/WG-PGR-5/11/2 Rev.1

Golden, M.H.N. (2002). A Report on an Investigation into Recurrent Epidemics of Pellagra in Kuito, Angola. Food and Nutrition Technical Assistance Project, Washington, D.C.

Goodland, R. (1997). Environmental sustainability in agriculture: diet matters. Ecological Economics 23:189-200

Grivetti, L.E & Ogle, B.M. (2000). Value of traditional foods in meeting macro- and micronutrient needs: the wild plant connection. Nutrition Research Reviews 13:31-46

Guarino, L., Friis-Hansen, E. (1995). Collecting plant genetic resources and documenting associated indigenous knowledge in the field: a participatory approach. In: L Guarino, V Ramanatha Rao and R Reid (editors). Collecting Plant Genetic Diversity. CAB International, Wallingford, UK. pp. 345–365.

Hatløy, A., Torheim, L.E., Oshaug, A. (1998). Food variety - a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. European Journal of Clinical Nutrition 52:891-8

Hawtin, G. (2011) "Whither genebanks?" presented at To Serve and Conserve: European Plant Genetic Resources Conference 2011, Wageningen, NL http://www.epgrc2011.nl/docs/5-0945-Hawtin.pdf

Jarvis, A., Upadhyaya, H., Gowda, C.L.L., Aggarwal, P.K., Fujisaka, S., Anderson, B. (2010). Climate Change and its effect on conservation and use of plant Genetic Resources for Food and Agriculture and associated biodiversity for food security. Thematic Background Study. FAO Rome. 27 p.

Johns, T., Eyzaguirre, P.B. (2006). Linking biodiversity, diet and health in policy and practice. Proceedings of the Nutrition Society 65:182-9

Katz, S.H. (1987). Food and Biocultural Evolution: A model for the Investigation of Modern Nutritional Problems. In Nutritional Anthropology, ed. F Johnston. New York: Alan R. Liss, Inc.

Katz, S.H., Hediger, M.L., Valleroy, L.A. (1974). Traditional Maize Processing Techniques in the New World. Science 184:765-73

Kunkel, G. (1984). Plants for Human Consumption. Koenigstein, West Germany: Koeltz Scientific Books

Lira, R., Casas, A., Rosas-López, R., Paredes-Flores, M., Pérez-Negrón, E., Rangel-Landa, S., Solís, L., Torres, I., & Dávila, P. (2009). Traditional Knowledge and Useful Plant Richness in the Tehuacán–Cuicatlán Valley, Mexico. Economic Botany, 63(3), 271-287.

Martin, G.J. (1995) Ethnobotany: A Methods Manual. People and Plants Conservation Manuals, Volume 1. Chapman and Hall, London.

McCullough, M.L., Feskanich, D., Stampfer, M.J., Giovannucci, E.L., Rimm, E.B., (2002). Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. American Journal of Clinical Nutrition 76:1261-71

Millennium Ecosystem Assessment (2005). Ecosystems and human well-being: biodiversity synthesis. Washington, DC., World Resources Institute.

Muthoka, P., Wagura, A., Kariuki, P., Kirika, P., Gaya, H., Mbithe, C., Mbale, M. (2010) Selected Useful Plant Species of Tharaka – Kenya: A Guide to Seed Collection, Propagation and Use. National Museums of Kenya, Nairobi.

Nyamwamu, B., Bosibori, E., Maundu, P., Kibet, S., McBurney, R.P. (2005). Needs Assessment with TATRO Women's Group in Western Kenya for the Conservation and Sustainable Utilisation of Traditional Food Plants. National Museums of Kenya, Nairobi.

Purvis, G., Anderson, A., Baars, J-R., Bolger, T., Breen, J., (2009). AG-BIOTA – Monitoring, Functional Significance and Management for the Maintenance and Economic Utilisation of Biodiversity in the Intensively Farmed Landscape: STRIVE Report Series No. 21. Wexford, Ireland: Environmental Protection Agency.

Royal Botanic Gardens Kew (2008). 'Difficult' Seeds Project. Retrieved May 16, 2011 from:http://www.kew.org/science-research-data/kew-in-depth/difficult-seeds/index.htm.

Royal Botanic Gardens Kew (2010). Seed Information Database (SID). Version 7.1. Retrieved May 16, 2011 from: http://data.kew.org/sid/

Savige, G.S. (2002). Can food variety add years to your life? 2nd Sanitarium International Nutrition Symposium, pp. S637-S41. Melbourne, Australia: Blackwell Publishing Asia

Slattery, M.L., Berry, T.D., Potter, J., Caan, B. (1997). Diet diversity, diet composition, and risk of colon cancer (United States). Cancer Causes & Control 8:872-82

U.K. Food Standards Agency (2009). Nutrition Essentials. http://www.eatwell.gov.uk/healthydiet/nutritionessentials/

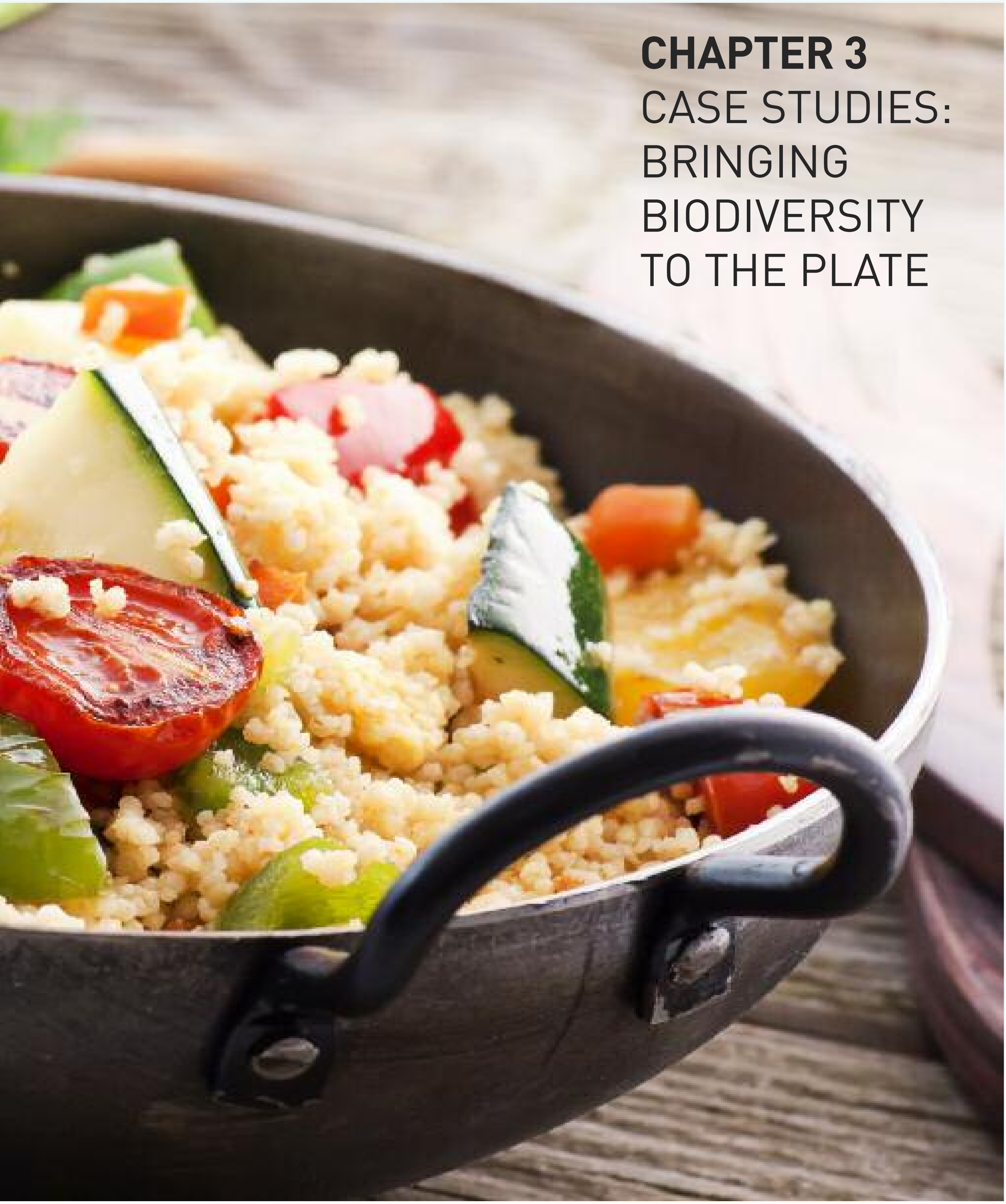
Ulijaszek, S.J., Strickland, S.S. (1993). Nutritional Adaptation. In Nutritional Anthropology Proespects and perspectives, p. 176. London: Smith-Gordon & Co.

Wahlqvist, M.L., Lo, C.S., Myers, K.A. (1989). Food variety is associated with less macrovascular disease in those with type II diabetes and their healthy controls. J Am Coll Nutr 8:515-23

WHO (Europe) (2003). Food based dietary guidelines in the WHO European Region. Rep. EUR/03/5045414 E79832, World Health Organization, Europe, Copenhagen, Denmark

Wisemann, D., Hoddinott, J., Aberman, N-L., Ruel, M. (2006). Validation of Food Frequency and Dietary Diversity as Proxy Indicators of Household Food Security. Final report submitted to the World Food Programme, Rome., United Nations World Food Programme Via C.G. Viola 68/70, Parco de' Medici, 00148, Rome, Italy

CHAPTER 3 CASE STUDIES: BRINGING BIODIVERSITY TO THE PLATE



BIODIVERSITY AND SUSTAINABILITY OF INDIGENOUS PEOPLES' FOODS AND DIETS

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Abstract
Indigenous Peoples living in their rural homelands and intact ecosystems retain a vast knowledge of biodiversity in food resources. Living in historical continuity over thousands of years implicitly recognizes the sustainability of their local food system. However, recent stresses to cultures and ecosystems, globalization of industrially produced foods, and simplification of diets have created commonalities for Indigenous Peoples for severe financial poverty, discrimination, disadvantage and challenges to nutrition and health. This report summarizes a ten-year programme of research and health promotion with 12 cultures of Indigenous Peoples in different parts of the world. Following methods development for documentation of local food systems of rural Indigenous Peoples, research highlighted a vast diversity in food species and their patterns of use. Dietary measures were used to evaluate improved use of local food resources that were emphasized in programmes and policy developments to sustainably improve diets and food and nutrition security in these areas. Effective cross-cutting strategies were participatory decision-making for research and intervention activities, focus on locally available cultural food species, capacity development and networking, educational activities with youth, and use of media to strengthen local perceptions of local food qualities. The interventions are ongoing, and several have been successful in scaling up their activities to other communities in the regions. Addressing threats to cultural and ecosystem sustainability and improving access to local traditional food will improve use of biodiverse food resources by Indigenous Peoples, enhance dietary quality, and improve sustainable food and nutrition security.

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1. Introduction

Indigenous Peoples are recognized by the United Nations as having historical continuity with ancestral territory and society, and as stewards of vast areas of biodiversity in their rural homelands. There are more than 370 million Indigenous Peoples in 90 countries, who speak more than 4 000 languages (Bartlett *et al.*, 2007; UNPFII, 2009). Sustainability of a local indigenous diet is presumed if a culture has occupied a territory for a very long time in harmony with nature, respecting and learning from the natural world and the bounty it provides to sustain community life and cultural ways of knowing and doing. If a culture survived through history to the present day, the diet was necessarily nutritionally complete; although recognition is given to the constant change and evolution experienced in natural ecosystems.

Our programme has been especially significant in its recognition that Indigenous Peoples in both developed and developing countries are often the most at risk populations within nations for issues related to both undernutrition and overnutrition, because they often experience the most severe financial poverty and disparities in health (Gracey and King, 2009; Reading, 2009). The transition to oversimplification of diets away from food resource diversity generated by healthy ecosystems is a global phenomenon that especially affects Indigenous Peoples dependent on ecosystems that are under stress (UNPFII, 2009).

In this context our research has focused on understanding the foods and diets of Indigenous Peoples in rural territories, and the treasures of knowledge these hold. Specifically, we focused on 12 long-evolved cultures in defined ecosystems in different parts of the world. Our objective has been to inquire into the food biodiversity, to understand the unique species and subspecies/varieties/cultivars known with traditional knowledge and how these continue to be cultivated, hunted, fished or gathered and then prepared and appreciated with cultural knowledge and techniques. The overall goal is to guide the use of this knowledge by communities for nutrition and health promotion activities that improve wellness.

2. Methods

Using participatory research methods created through the Centre for Indigenous Peoples' Nutrition and Environment at McGill University (CINE), Canada (Sims and Kuhnlein, 2003), staff from CINE in cooperation with the Nutrition Division of the Food and Agriculture Organization of the United Nations (FAO) developed a methodology with partners in Asian settings. This provided a framework to food systems documentation, structure to processes for scientific nomenclature, laboratory studies on nutrient composition, and qualitative methods to understand local food meanings and use (Kuhnlein *et al.*, 2006). Subsequently, in cooperation with the Task Force on Indigenous Peoples' Food Systems and Nutrition of the International Union of Nutritional Sciences (IUNS) the methodology was applied and adapted within 12 unique cultural case studies of Indigenous Peoples residing in different rural ecosystems in various global regions: Awajún (Peru), Ainu (Japan), Baffin Inuit (Canada), Bhil (India), Dalit (India, Gwich'in (Canada), Igbo (Nigeria), Ingano (Colombia), Karen (Thailand), Maasai (Kenya), Nuxalk (Canada), and Pohnpei (Federated States of Micronesia). In each area, communities of Indigenous People collaborated with in-country academic partners and CINE for research in two phases: 1) documentation of the food system including use of both local traditional food and imported market-sold food, food species and food component data; and 2) use of this knowledge to implement health promotion interventions using culturally sensitive and environmentally relevant elements of the local food systems. Team members communicated electronically and team leaders met annually over a ten year period (2001–2010) to discuss methods, results and strategies for implementing health promotion policies and activities (Figure 1) (Kuhnlein *et al.*, 2006). Funding from a variety of sources was obtained to develop and implement interventions to improve

Figure 1. Case study partners meeting in Bellagio, Italy, in 2008 to discuss research process, results and health promotion strategies (kp studios).

dietary intake and health by using elements of the diverse food systems of Indigenous Peoples in several of the case studies. Interventions were created with participatory methods with local teams from case studies working with the Nuxalk, Dalit, Gwich'in, Inuit, Ingano, Awajún, Karen and Pohnpei. The Ainu developed an education intervention that stressed cultural revival and traditional knowledge taught to youth.

3. Results

Each case study completed a report of their findings and prepared a chapter for a book published and distributed widely by FAO (Kuhnlein *et al.*, 2009). In addition, several colourful food-system posters in recognition of the International Decades of the World's Indigenous Peoples were widely distributed by FAO (FAO and CINE, 2004-06). Eight 20-minute documentary films were created and are posted free on the internet (KP Studios, 2009).

3.1 Diversity of species documented and variation in extent of use

As anticipated, there is an astonishing diversity of species known and used, with up to 380 species used annually within one culture. There is also wide variation in the extent of use of these foods, varying from less than 10 percent to up to 95 percent of daily energy provided by local species in the ecosystem

(Table 1).

Indigenous Group	Energy %	No. of species/ varieties
Awajún (Peru)	93	223
Bhil (India)	59	95
Dalit (India)	43	329
Gwich'in (Canada)	33	50
Igbo (Nigeria)	96	220
Ingano (Colombia)	47	160
Inuit (Canada)	41	79
Karen (Thailand)	85*	387
Maasai (Kenya)	6	35
Nuxalk (Canada)	30*	67
Pohnpei (Micronesia)	27	381

* Estimated for adults.

Table 1. Adult dietary energy as local traditional food and number of species/varieties in the food system.
(Reproduced with permission from: Kuhnlein HV, in: Kuhnlein, Erasmus, Spigelski, 2009, pg 5)

Ways of cultivating, harvesting, processing and preparing the foods for families were shown to be fascinating. However, many species/varieties documented did not have scientific identifications and nutrition composition analyses completed (Kuhnlein *et al.*, 2009).

As shown in Table 1 the locally used food species numbers varied considerably depending on the ecosystem. Team members reported a low of 35 food species used in the arid, drought-prone zones of Kenya where Maasai reside, and up to more than 380 unique food species/varieties documented for tropical rain forests. The Karen in Thailand (387 species) and Pohnpei culture of the Federated States of Micronesia (381 species/varieties), Dalit in Zaheerabad region of India (329 species), Awajún in Peru (223 species) and Igbo of Nigeria (220 species) all had extensive, complex food systems and rich cultural traditions using them. However, the extent of use of species for providing daily energy consumption also varied (Table 1), with up to 100 percent of adult energy from local food resources for the Awajún and Igbo. Research with the Karen, Bhil, Maasai, Pohnpei and Dalit showed that commercial (or donated) refined staples replaced traditional foods in the diet; the Canadian Gwich'in, Inuit and Nuxalk peoples were using less than 45 percent of energy as traditional species with the commercial foods derived primarily from refined wheat flour, fats and sugar. The Ainu in Japan used very little traditional food in their daily diet, and could not recognize all the available species or record the extent of energy consumed from them (Kuhnlein *et al.*, 2009).

3.2 Indigenous Peoples' food and nutrition interventions for health promotion and policy

Eight interventions were developed with diverse resources from within the communities as well as from external sources. Funding and logistic constraints necessitated work with unique small populations where meaningful control groups were not available. This led to before- and after-intervention research designs using both qualitative and quantitative measures. Special considerations were needed to build local cultural pride, develop cross-sectoral planning and action, and create energetic and enthusiastic advocates for community goodwill. All interventions required several years to completion with evaluation documentation, even while the interventions were sustained and continued to build healthy diets in communities (Kuhnlein *et al.*, in press).

3.3 Cross-cutting themes of interventions

Leadership within the nine interventions agreed that activities targeting children and youth were crucial to build long-term change into community wellness. Not only were activities built to improve nutrition and health of young people, but to create the cultural morale and knowledge based in culture and nature for their learning in formal and informal settings. Traditional wildlife animal and plant harvest and agricultural activities based in local traditional crops were important in youth learning in case studies conducted with the Baffin Inuit, Gwich'in, Nuxalk, Inga, Pohnpei, Karen and Dalit. Ainu youth experienced classroom activities in traditional food preparation.

Broad-based education activities took place in intervention communities that stressed the local cultural food diversity and its benefits for understanding the ecosystem as well as for health in harvest, use and human nutrition. First steps were to use knowledge generated in Phase 1 to develop positive attitudes about local traditional food so that case study leaders could then foster behaviours at all levels to increase use of these foods. In the Pohnpei case study, for example, agricultural leaders provided training in agricultural practices and provided seedlings and young trees for planting in yards adjacent to community homes. In the Karen case study, school children were taught how to harvest from the forest, and also how to plant, cultivate and harvest their local traditional agricultural crops in village areas, which was followed by popular activities of harvesting and preparation of meals for their families. In the Gwich'in area, youth in middle school and high school prepared dried caribou meat and shared it with the elders in their community; and in the Inuit project elders made radio programmes that were shared for learning with youth in their school classes. These are just some of the examples showing how communities created their own meaningful activities.

Engagement with government offices was also an important cross-cutting theme. While some case study partners did not have regular communication with government offices, others did. When the communication was fruitful, it contributed a lot to the intervention. For example the Pohnpei case study worked well with ministries responsible for agriculture, health, education, and the public media to further their goals. People knew each other and connected easily. This was possible, in part, because of the pro-active leadership of the project, but also because both the state and national governments were in the same town on the same island in the Federated States of Micronesia. Another example is the good relationships the Karen project had with the Ministry of Health in Kanchanaburi Province, as well as the local border control officers who helped with activities in the schools. There was also good attention given by the Thai royal family to the project, which raised project profile with government agencies throughout Thailand. On the other hand, government offices are not always helpful to Indigenous Peoples if there is conflict over land or other resources and if there is systematic disadvantage based on discrimination; such discrimination is often manifest in lack of access to healthcare in rural areas where Indigenous Peoples live.

Throughout all intervention projects committed community leaders and academics became effective advocates dedicated to the success of the project and responsible for developing the capacity-building activities and empowerment of residents to use the local food systems based in culture to their best advantage. Capacity-building was the hallmark of the Dalit project in the Zaheerabad district of Hyderabad, India, where Dalit women were given opportunities for education, especially in media productions, and in finding education opportunities for their children. This resulted not only in increased literacy, but in building self-worth and commitment to using and showcasing their unique foods in many different ways, such as in culinary food fairs, computer cafes, and film festivals. All projects engaged project assistants to help with food activities and the research foundations of the interventions. A popular activity in most case studies was creation of photo-enhanced information books on the food system to share in schools, public places and to be distributed to village homes. Local assistants, primarily women, were leaders in networking, and in helping others to "learn by doing", and to gain participatory agreements on how to best move the projects forward. The best successes occurred in bringing together the community's social capital in the form of hunters, farmers, fishers, elders, political leaders, teachers and spiritual leaders to advance from the "bottom up" the local cultural principles of what is good food and how to harvest and best use it.

None of the interventions had focus in single nutrient solutions to single nutrient inadequacies. Rather, the strategies employed worked to improve food provisioning from local sources, and to improve dietary biodiversity for all age groups. All projects were in rural areas without access to large markets that stressed industrial food products. When market (store bought) food was discussed, it was in the context of how to increase the demand and supply of nutrient-rich, good quality foods with minimal processing.

4. Discussion

With positive attitudes and confidence that the local food is credibly healthy, local networks in these communities of Indigenous Peoples have developed a wide range of activities to create community empowerment for sustained use and food and nutrition security. However, sustainability of these foods for Indigenous Peoples depends on cultural and ecosystem sustainability. It depends on continued cultural expression; for example, to use food harvesting and appreciation as an avenue in youth education and fitness training, as well as guiding understanding of their natural surroundings. It also depends on ecosystem conservation to protect the food provisioning lands, waters, forests and other essential resources.

Measures of intervention programme success with small populations of culturally defined Indigenous Peoples preclude measurements that depend on large sample sizes and control groups. With the exception of improved underweight, changes in anthropometric measures, whether to improve stunting or reduce obesity, were not found within short time periods, as expected. More importantly, the root causes of being "big" or "small/short" were identified and addressed with expectation for long-term improvements in general community wellness. Measures of improved financial security were found within our case studies to be less important than perceptions of improved community wellness. In fact, in the Thai Karen case study, leaders expressed that "food is a part of happiness", and that it is meaningless to try to measure it with money.

Many policies that fostered improved food and nutrition security were developed, and are discussed more fully in Kuhnlein *et al.* (in press). It is crucial to maintain databases of health statistics that are disaggregated by culture and ethnic groups within nations to identify areas of health risks and to track change. Only by knowing the risks can they be addressed with multisectoral government agencies which logically include those responsible for health, human rights, education, agriculture, culture, commerce, environment and its conservation, energy and transportation – ministries that need to form cooperative partnerships to protect ecosystems and cultures against degradation and loss of biodiversity in both rural and other population areas where Indigenous Peoples live. Respecting and protecting indigenous knowledge and the peoples who hold this knowledge can lead to better understanding of research policies to use the genetic potential for crops to become resistant to pests, heat and drought.

It is well recognized that Indigenous Peoples experience challenges in expressing their human right to adequate food (Knuth, 2009). One serious challenge is that of climate change, which is expected to continue and threaten many ecosystems where Indigenous Peoples live. This then impacts the human rights of Indigenous Peoples who lack the physical, technological, economic and social resources to cope with resulting ecosystem damage which causes risk to biodiversity and sustainability of the diets that can be provisioned from it (Damman, 2010).

5. Conclusions

In all areas where our programme has been in effect, there are several threats to cultural sustainability and to ecosystem sustainability, which in turn threaten the biodiversity of sustainable diets of the resident Indigenous Peoples. Each case study and its intervention have impressive stories of challenges and successes that can inspire communities of Indigenous Peoples everywhere to become proactive in protecting their food systems. By documenting these unique food resources and their cultural and ecosystem requirements, we recognize the imperatives to protect these treasures of human knowledge to benefit Indigenous Peoples and all humankind now and into the future.

Understanding the challenges and successes of improving access to local food and improving dietary intakes and food and nutrition security of rural Indigenous Peoples provides important lessons. While it can be supposed that strategies with any group of disadvantaged people will bring success within a setting of Indigenous Peoples, this is not necessarily so unless the issues of rural inaccessibility, serious discrimination, and respect and protection of cultures and ecosystems that provide wellness are addressed. On the other hand, it is very likely that health promotion lessons based in local food systems that resonate with Indigenous Peoples will find a measure of meaning for practitioners who address public health in any community of disadvantaged people.

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References

Bartlett, J.G., Madariega-Vignudo, L., O'Neil, J.D. & Kuhnlein, H.V. (2007) Identifying Indigenous peoples for health research in a global context: a review of perspectives and challenges. International Journal of Circumpolar Health 66(4):287-307.

Damman, S. (2010). Indigenous Peoples, rainforests protection and climate change. SCN News No. 38: 63-68. United Nations System SCN, Geneva.

FAO and CINE (2004-6). Indigenous Foods Posters. www.fao.org/infoods/biodiversity/posters_en.stm

Gracey, M. & King, M. (2009). Indigenous health Part 1: Determinants and disease patterns. Lancet, 374(9683): 65-75.

Knuth, L. (2009). The right to adequate food and indigenous peoples. How can the right to food benefit indigenous peoples? Rome, Food and Agriculture Organization of the United Nations. 56 pp. (available at http://www.fao.org/righttofood/publi09/ind_people.pdf)

KP Studios. (2009). www.indigenousnutrition.org

Kuhnlein, H.V., Smitasiri, S., Yesudas, S., Bhattacharjee, L., Li, D.,S Ahmed, S.& Collaborators. (2006). Documenting Traditional Food Systems for Indigenous Peoples: International Case Studies. Guidelines for Procedures. http://www.mcgill.ca/cine/research/global/

Kuhnlein, H.V., Erasmus, B., Creed-Kanashiro, H., Englberger, L., Okeke, E., Turner, N., Allen, L., Bhattacharjee, L., *et al.* (2006). Indigenous Peoples' food systems for health: Finding interventions that work. Public Health Nutrition. 9(8):1013-1019.

Kuhnlein, H.V., Erasmus, B. & Spigelski, D. (2009) Indigenous peoples' Food Systems: the Many Dimensions of Culture, Diversity and Environment for Nutrition and Health. United Nations Food and Agriculture Organization, Rome. Also available on line at http://www.fao.org/docrep/012/i0370e/i0370e00.htm

Kuhnlein, H.V., Erasmus, B., Spigelski, D. & Burlingame, B. (in press, 2011). Indigenous Peoples Food Systems and Wellbeing: Interventions and Policies for Healthy Communities. United Nations Food and Agriculture Organization, Rome.

Reading, J. (2009). The crisis of chronic disease among Aboriginal Peoples: a challenge for public health, population health and social policy. Victoria, University of Victoria. 185 pp.

Sims, J. & Kuhnlein, H.V. (2003) Indigenous Peoples Participatory Health Research. Planning and management. Preparing Research Agreements. Geneva: World Health Organization. 35 pp. www.who.int/ethics/indigenous_peoples/en/index1.html

United Nations Permanent Forum on Indigenous Issues, 2009. State of the World's Indigenous Peoples. http://www.un.org/esa/socdev/unpfii/documents/SOWIP_web.pdf, (page 4- the concept of Indigenous Peoples; pages 155-187 Cunningham M – health)

REVISITING THE VITAMIN A FIASCO: GOING LOCAL IN MICRONESIA

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Abstract
The term “vitamin A (VA) fiasco” refers to the global programme for universal VA supplementation, which has been challenged for its validity and wisdom. The Federated States of Micronesia (FSM) situation presents an example where VA supplementation has vied with food-based approaches for resources. The FSM has experienced many lifestyle changes since the 1970s, including a shift to imported processed foods and neglect of traditional foods. This led to serious health problems, including VA deficiency, diabetes, heart disease and cancer. In 1998 efforts were initiated to identify FSM foods that might alleviate VA deficiency. This led to discovering a yellow/orange-fleshed banana variety, Karat, containing 2 230 μg/100 g of the provitamin A carotenoid beta-carotene, 50 times more than in white-fleshed bananas. Other Micronesian yellow- and orange-fleshed carotenoid-rich varieties of banana, giant swamp taro, breadfruit and pandanus were later identified, also containing rich contents of vitamins and minerals. In a global health study led by the Centre for Indigenous Peoples’ Nutrition and Environment, the Pohnpei, FSM traditional food system was documented. A two-year community-based, interagency, intervention was implemented, focused on increasing local food production and consumption. Multiple methods were used, including awareness, workshops, horticulture, cooking classes, mass media, posters, print materials, postal stamps, youth clubs, school activities, farmers’ fairs, competitions, email and slogans: “Go Yellow” and “Let’s Go Local”. Results showed an increase in banana and taro consumption, varieties consumed, and improved attitudes towards local food. Carotenoid-rich banana varieties including Karat, which had not previously been marketed, became regular market items. Local food take-outs not previously sold became common sale items. The campaign stimulated great interest as an awareness success in FSM and throughout the region, stimulating interest to applying this approach to other Pacific islands. The campaign could, however, have a greater impact with greater allocation of resources to this food-based approach.

1. Introduction

1.1 Vitamin A fiasco

The term “the vitamin A fiasco” as discussed by Latham (2010) refers to the large global programme for universal VA supplementation, which has been challenged for its validity and wisdom. The rational of this programme was to decrease overall child mortality, but the article shows the weak scientific basis for this. No study has shown the proof of success of the vitamin A supplementation programmes. The programme has utilized huge amounts of funds in 100 countries. As funds were allocated to the vitamin A programme, this blocked food-based approaches for improving vitamin A status. This has also taken place in Micronesia, where there are limited resources plus the mentality that once the vitamin A supplements have been given, the problem has been dealt with.

This paper presents a success story of food. The areas covered are:

- How we first carried out food composition studies on Micronesian foods and identified yellow- and orange-fleshed varieties of local foods rich in provitamin A carotenoids and other nutrients that could be promoted to alleviate the serious problems of vitamin A deficiency and other health problems in Micronesia.
- How we developed our food-based “Go Local” programme with the aim to improve nutrition and health, and showing success in a target community.

1.2 Background to the situation in the Federated States of Micronesia

The Federated States of Micronesia (FSM), total population of 102 624, comprises four states: Pohnpei, Chuuk, Yap and Kosrae, altogether with 607 islands (FSM, 2010).

Since the 1970s, there have been great lifestyle and dietary changes in Micronesia. The traditional local foods include the starchy staples, including breadfruit, banana, taro, yam and pandanus, along with coconut, fish and seafood, and various fruits. There has been a great diversity of these staple foods. For example, there are 133 breadfruit, 171 yam, banana, and 24 giant swamp taro varieties (Raynor, 1991).

However in recent years there has been a shift to nutrient-poor imported processed foods, such as refined white rice, flour, sugar, fatty meats and other processed foods (Englberger *et al.,* 2003d).

Imported white rice, which is often not enriched, has become a major staple in the diet. This has changed the nutrient intake of the population as rice also contains no provitamin A carotenoids and is low in fibre, whereas local staples contain at least some carotenoids and are rich in fibre. Previously there was also little known about the differences in nutrient content between the many varieties of the staple crops as few food composition studies had been carried out on FSM foods.

The shift from traditional foods to imported processed foods and lifestyle changes in FSM led to a serious problem of vitamin A deficiency, which causes vision problems, increased infection and mortality. The first documentation of vitamin A deficiency in FSM was in Chuuk (Lloyd-Puryear *et al.,* 1989). Of 60 randomly selected children, 12 percent had night blindness and 5 percent had Bitot's spots, far exceeding the World Health Organization cut-offs for a public health problem (WHO, 1995). That study maintained that vitamin A deficiency was an emerging problem as there was no term for night blindness in the local language and old people did not know of the problem.

Following the identification of the problem in Chuuk, studies were done in the other three states, showing that over half of FSM under-5-year olds had vitamin A deficiency (Yamamura, 2004).

To alleviate the vitamin A deficiency problem, green leafy vegetables were first promoted as these vegetables are easy to grow and are rich in beta-carotene, the most important of the provitamin A carotenoids. Once consumed, beta-carotene is converted to vitamin A in the body. However, interviews with local members of the community revealed that green leafy vegetables had not been consumed previously as traditional foods, were not well accepted and were considered as food for the pigs.

It was clear that if people had not consumed green leafy vegetables in the past and did not have vitamin A deficiency, there must have been some traditional foods that had protected people against that health problem. This question led to the study to identify those foods that protected Micronesians from vitamin A deficiency in the past and could also alleviate the problem currently.

2. Methods

Overall an ethnographic participatory community-based and interagency approach was taken in assessing the foods, documenting the traditional food system and gaining insight on how to improve the situation. As vitamin A deficiency was diagnosed in the 1990s, efforts were first made in identifying local foods that are rich in provitamin A carotenoids or vitamin A and would alleviate vitamin A deficiency.

The results of the analyses were then used to promote the local foods and an overall approach was developed to awaken interest in local foods and the traditional food system. This was helped greatly by the involvement with a global health study led by the Centre for Indigenous Peoples' Nutrition and Environment. Pohnpei was selected as one of the 12 case studies in the CINE programme for documenting and promoting traditional food systems. Specific guidelines were followed (Kuhnlein *et al.,* 2005).

3. Results and discussion

3.1 Analyses of local foods

Karat, a yellow-fleshed variety of banana, was analysed and found rich in beta-carotene, the most important of the provitamin A carotenoids. Foods rich in provitamin A carotenoids protect against vitamin A deficiency (McLaren and Frigg, 2001). Karat contained up to 2 230 µg beta-carotene/100 g (Englberger *et al.,* 2006). An orange-fleshed banana, Utin Iap, contained 8 508 µg beta-carotene. This compares to 30 µg beta-carotene for common banana. It was shown that the carotenoid content was greater in those varieties with the greater yellow or orange flesh colouration. This led to the "Yellow Varieties" campaign and the slogan "Go Yellow". Both slogans helped to brand the movement and provide further interest.

A series of studies were conducted to analyse other banana, giant swamp taro, breadfruit and pandanus varieties, with potential for rich carotenoid content due to the yellow or orange flesh colouration. The results showed that the varieties with greater yellow or orange flesh colouration did have a greater carotenoid concentration (Englberger *et al.*, 2003a,b,c, 2008, 2009a, 2010d). These foods were also shown to be rich in vitamins, minerals including zinc, calcium, iron, and fibre.

Epidemiological studies also show that carotenoid-rich foods protect against cancer, heart disease and diabetes (WCRF/AICR, 2007; Kritchevsky, 1999; Coyne *et al.,* 2005). These non-communicable diseases have become the major health problems in the FSM. For example, in Pohnpei, 32 percent of adults now are afflicted with diabetes (WHO, 2008). Thus, the yellow-fleshed, carotenoid-rich foods and varieties can play a double role. They can help to protect against vitamin A deficiency disorders and also help against these non-communicable diseases.

3.2 Formation of a non-governmental organization

The Island Food Community of Pohnpei (IFCP) was chartered as a non-governmental organization in 2004, and adopted the Go Local slogan in 2005. With the formation of an organization devoted entirely to the promotion and research of local foods, important progress was made in going forward with local food promotion.

3.3 GO LOCAL slogan

One of the important parts of the intervention to increase production and consumption of local foods was the reviving of the slogan "Go Local", introduced first by a government officer Bermin Weilbacher in the 1980s (Englberger *et al*., 2010c). As many people were already familiar with the term and it captured the many broad aspects of what local foods involve, it caught on quite quickly. It provided "project branding" and gave a unifying aspect to the campaign.

The term refers to a food-based approach to improving health, and increasing food production and consumption. The term was changed slightly to "Let's go local" in order to soften the term and make it a group activity. Billboards, t-shirts, songs and promotional pens were made to present the slogan and it became well known and popular.

The term also refers to many other important benefits. This led to the development of an acronym "CHEEF" to describe the chief or many benefits of local food. These are Culture, Health, Environment, Economics and Food security. Thus, the campaign not only encouraged to "go local" but also emphasized the many reasons on why to go local.

3.4 Involvement with the CINE-led global health project

As part of the global health study led by the Centre for Indigenous Peoples' Nutrition and Environment, the traditional food system in Pohnpei, FSM, was documented (Englberger *et al.,* 2009b) and promoted (Englberger *et al.,* 2010a). A target community was selected, Mand Community, along with these criteria: around 500 in population, rural, accessible and willingness to participate. The first phase focused on the documentation (around three months) of the traditional food system, which is documented in Chapter 6 of the published book by CINE and Food and Agriculture Organization of the United Nations (Kuhnlein *et al.,* 2009; Englberger *et al.,* 2009b).

The second phase focused on the implementation of a two-year community-based, interagency, participatory intervention, aiming at increasing local food production and consumption.

Multiple methods were used, including awareness, workshops, horticulture, cooking classes, mass media, posters, print materials, on postal stamps, youth clubs, school activities, farmers' fairs, competitions, email (Englberger *et al.,* 2010b), slogans: "Go Yellow" and "Let's Go Local", and the use of local food policies.

The second phase also included the evaluation (Kaufer *et al.,* 2010).

The project showed these successes of promotion of local food:

- Increase in the frequency of consumption of banana and giant swamp taro.
- Increase in the number of banana varieties planted.
- Increase in dietary diversity, in particular, vegetables.
- A positive change in attitude towards local foods in the community.

3.5 Other documentations of island foods

Two chapters, one on banana and one on taro, were written for the book titled "Ethnobotany of Pohnpei: Plants, People and Island Culture" (Balick *et al.,* 2009), highlighting the rich content of the many varieties of banana and taro. The book also highlighted our involvement in the CINE-led case study and the "go local" campaign.

3.6 Local food policies

Local food policies were defined broadly and included community policies to use only local foods at meetings and workshops held by the Island Food Community of Pohnpei and by the community in Mand. Later this further developed into a policy that Mand Community adopted to ban soft drinks in their community meetings. Other Pohnpei communities also adopted bans on soft drinks in their events, including the Pingelapese Peoples' Organization, Inc. and the Kosrae Kolonia Congregational Church. A national policy was established with the FSM President signing a food security proclamation that all FSM national events use local food at their events. In order to help promote rare yellow- and orange-fleshed banana varieties, a general policy was also adopted by IFCP to buy just those varieties for their meetings and events, in place of the white-fleshed banana variety that is most commonly consumed in Pohnpei as a ripe eating banana.

4. Lessons learned

Our lessons learned were many. Some of these were:

- Community- and interagency-based approach was important.
- Walk the Talk: To promote local foods, it was essential to use local foods.
- Repetition: Messages needed to be repeated many times.
- Mass media (radio, newspaper, email, videos, television) helped a lot.
- Face-to-face encounters were also important.
- Multiple methods: It is important to use a variety of methods.
- Slogans (Go Local and Go Yellow): These are important for branding and unity.
- Scientific approach: Community people wanted a scientific approach.
- Food analysis was critical to establishing the value of their local food.
- Assessment and evaluation of the work was important to show progress.
- Acknowledgement of everyone's involvement increased motivation and interest.
- Local food policies: These were important and are still being further developed.

Many people were not aware of how their diet and physical activity affected their health, and innovative methods were needed to help them gain this understanding. On the other hand, many people were more interested in the other values of local foods. Protecting cultural identity through the preservation of the traditional food system was very important for many people.

The economic, environmental and food security benefits were important as well to help put forth the broad benefits that locally grown food provide. The use of the CHEEF acronym was very helpful for explaining why we should "go local", namely for Culture, Health, Environment, Economics and Food security. In addition, and perhaps most important of all, it was important that the leaders of the activity were passionate about their work, that the activities planned were fun and that people carrying out the activities also be involved in planning them.

5. Conclusions

To conclude, a food-based approach has many advantages to vitamin A supplementation in alleviating vitamin A deficiency in Micronesia. Heed should be taken of the paper by Latham *et al*. (2010) referring to the universal vitamin A supplementation programme as a "fiasco" and the need to question its wisdom and validity. Vitamin supplementation programmes can block food-based approaches.

It should always be remembered that whole foods can provide a wealth of nutrients, whereas supplementation programmes may focus only on one or a few nutrients. Food-based approaches and local foods are important for many benefits. The "CHEEF" acronym stresses the benefits of local food, which are: Culture, Health, Environment, Economics and Food security. So let's support food-based approaches and let's go local!

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References

Balick, M.J. & Collaborators (2009). Ethnobotany of Pohnpei: Plants, People and Island Culture. Honolulu, University of Hawai'i Press.

Coyne, T., Ibiebele, T.I., Baade, P.D., Dobson, A., McClintock, C., Dunn, S., Leonard, D., Shaw, J. (2005). Diabetes mellitus and serum carotenoids: findings of a population-based study in Queensland, Australia. American Journal of Clinical Nutrition 82 (3), 685–693.

Englberger, L., Aalbersberg, W., Ravi, P., Bonnin, E., Marks, G.C., Fitzgerald, M.H., Elymore, J. (2003a) 'Further analyses on Micronesian banana, taro, breadfruit and other foods for provitamin A carotenoids and minerals', Journal of Food Composition and Analysis, vol 16 (2), 219-236

Englberger, L., Aalbersberg, W., Fitzgerald, M.H., Marks, G.C., Chand, K. (2003b) 'Provitamin A carotenoid content of different cultivars of edible pandanus fruit tectorius', Journal of Food Composition and Analysis, vol 16 (2), 237-247

Englberger, L., Schierle, J., Marks, G.C., Fitzgerald, M.H. (2003c) 'Micronesian banana, taro, and other foods: newly recognized sources of provitamin A and other carotenoids', Journal of Food Composition and Analysis, vol 16 (1), 3-19

Englberger, L., Marks, G.C., Fitzgerald, M.H. (2003d) 'Insights on food and nutrition in the Federated States of Micronesia: a review of the literature', Public Health Nutrition, vol 6 (1), 3-15

Englberger L, Schierle J, Aalbersberg W, Hofmann P, Humphries J, Huang A, Lorens A, Levendusky A, Daniells J, Marks GC, Fitzgerald MH (2006). Carotenoid and vitamin content of Karat and other Micronesian banana cultivars. International Journal of Food Science and Nutrition, 57, 399-418

Englberger, L., Schierle, J., Kraemer, K, Aalbersberg, W., Dolodolotawake, U., Humphries, J., Graham, R., Reid, A.P., Lorens, A., Albert, K., Levendusky, A., Johnson, E., Paul, Y., Sengebau, F. (2008) 'Carotenoid and mineral content of Micronesian giant swamp taro (Cyrtosperma) cultivars', Journal of Food Composition and Analysis, 21, 93-106

Englberger, L., Schierle, J., Hoffman, P, Lorens, A., Albert, K., Levendusky, A., Paul, Y., Lickaneth, E., Elymore, A., Maddison, M., deBrum, I., Nemra, J., Alfred, J., Vander Velde, N., Kraemer, K. (2009a) 'Carotenoid and vitamin content of Micronesian atoll foods: pandanus (Pandanus tectorius) and garlic pear (Crataeva speciosa) fruit', Journal of Food Composition and Analysis, vol 22 (1), 1-8

Englberger L, Lorens A, Levendusky A, Pedrus P, Albert K, Hagilmai W, Paul Y, Nelber D, Moses P, Shaeffer S, Gallen M. (2009b) 'Chapter 6: Documentation of the Traditional Food System of Pohnpei'. p 109-138. In: Kuhnlein, H.V., Erasmus, B. and Spigelski,D. eds. Indigenous Peoples' Food Systems: the Many Dimensions of Culture, Diversity and Environment for Nutrition and Health. FAO of the UN

Englberger, L., Kuhnlein, H.V., Lorens, A., Pedrus, P., Albert, K., Currie, J., Pretrick, M., Jim, R., Kaufer, L. (2010a) 'Pohnpei, FSM case study in a global health project documents its local food resources and successfully promotes local food for health', Pacific Health Dialog, vol 16 (1), 121-128

Englberger, L., Lorens, A., Pretrick, M., Spegal, R., Falcam, I. (2010b) ' "Go Local" Island Food Network: Using email networking to promote island foods for their health, biodiversity, and other "CHEEF" benefits', Pacific Health Dialog, vol 16 (1), 41-47

Englberger, L., Joakim, A., Larsen, K., Lorens, A., Yamada, L. (2010c) 'Go local in Micronesia: Promoting the 'CHEEF' benefits of local foods', Sight and Life Magazine 1/2010, 40-44

Englberger, L., Lorens, A. Pretrick, M., Raynor, B., Currie, J., Corsi, A., Kaufer, L., Naik, R.I., Spegal, R., Kuhnlein, H. V. (2010d) Chapter 13: Approaches and Lessons Learned for Promoting Dietary Improvement in Pohnpei, Micronesia pp , in: Thompson, B. and Amoroso, L. eds. Combating Micronutrient Deficiencies: Food-based Approaches, Food and Agriculture Organization of the United Nations

FSM Government, Office of Statistics, Budget and Economic Management. (2002) 2010 FSM-wide Census of Population and Housing. Preliminary Counts. Palikir, Pohnpei, FSM National Government.

Kaufer, L., Englberger, L., Cue, R., Lorens, A., Albert, K., Pedrus, P, Kuhnlein, H.V. (2010) 'Evaluation of a traditional food for health intervention in Pohnpei, Federated States of Micronesia', Pacific Health Dialog, vol 16, no1, pp61-73

Kritchevsky, S.B. (1999) 'Beta-carotene, carotenoids and the prevention of coronary heart disease', Journal of Nutrition, 129, 5–8 .

Kuhnlein, H.V., Smitasiri, S., Yesudas, S., Bhattacharjee, L., Dan, L., Ahmed, S. (2005) Documenting traditional food systems of Indigenous Peoples: International case studies. Guidelines for procedures. Ste Anne de Bellevue, Centre for Indigenous Peoples' Nutrition and Environment

Kuhnlein, H. V, Erasmus, B. Spigelski, D. eds. (2009). Indigenous Peoples' Food Systems: the Many Dimensions of Culture, Diversity and Environment for Nutrition and Health. Rome, Food and Agriculture Organization of the United Nations and Centre of Indigenous Peoples' Nutrition and Environment.

Latham M. (2010) The great vitamin A fiasco. [Commentary] World Nutrition, May 2010, 1, 1: 12-45. Obtainable at www.wphna.org

Lloyd-Puryear M, Humphrey JH, West KP, Aniol K, Mahoney J, Keenum DG. Vitamin A deficiency and anemia among Micronesian children. Nutr. Res. 1989; 9: 1007–16.
McLaren, D.S., Frigg, M. (2001) Sight and Life Manual on Vitamin A Deficiency Disorders (VADD) 2nd ed., Basel, Task Force Sight and Life

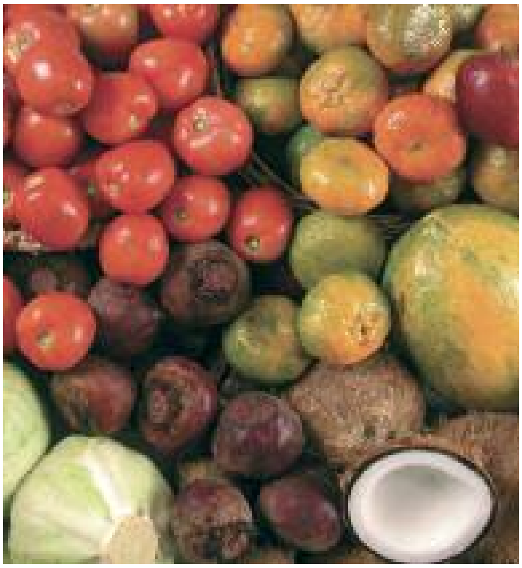
Raynor, B. (1991) 'Agroforestry Systems in Pohnpei – Practices and Strategies for Development: RAS/86/036 Field Document 4', FAO/UNDP South Pacific Forestry Development Programme

World Cancer Research Fund (WCRF)/American Institute for Cancer Research (AICR) (2007) Food, Nutrition, Physical Activity and the Prevention of Cancer: A Global Perspective. AICR, Washington, DC

World Health Organization (WHO). Global Prevalence of Vitamin A Deficiency. MDIS Working Paper #2. Micronutrient Deficiency Information System, WHO/NUT/95.3. Geneva: WHO, 1995.

World Health Organization (WHO) (2008) 'Federated States of Micronesia (Pohnpei) NCD risk factors STEPS report', Suva, WHO Western Pacific Region

Yamamura C, Sullivan KM, van der Haar F, Auerbach SB, Iohp KK. Risk factors for vitamin A deficiency among preschool aged children in Pohnpei, Federated States of Micronesia. J Trop Ped 2004; 50, 16-19.



EXPLORING NEW METRICS: NUTRITIONAL DIVERSITY OF CROPPING SYSTEMS

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Abstract
Historically, agricultural systems have been assessed on the basis of a narrow range of criteria, such as profitability or yields. Yet, these metrics do not reflect the diversity of nutrients provided by the system that is critical for human health. In this study we take a step to demonstrate how ecological tools can play a role in addressing nutritional diversity as an overlooked ecosystem service of agricultural systems.

Data on edible plant species diversity, food security and diet diversity were collected for 170 farms in three rural settings in sub-Saharan Africa. Nutritional FD metrics were calculated based on farm species composition and species nutritional composition. Iron and vitamin A deficiency were determined from blood samples of 90 adult women.

Nutritional FD metrics summarized the diversity of nutrients provided by the farm and showed variability between farms and villages. Regression of nutritional FD against species richness and expected FD enabled identification of key species that add nutrient diversity to the system and assessed the degree of redundancy for nutrient traits. Nutritional FD analysis demonstrated that depending on the original composition of species on farm or village, adding or removing individual species can have radically different outcomes for nutritional diversity. While correlations between nutritional FD, food and nutrition indicators were not significant at household level, associations between these variables were observed at village level.

This study provides novel metrics to address nutritional diversity in farming systems and examples of how these metrics can help guide agricultural interventions towards adequate nutrient diversity. New hypotheses on the link between agrodiversity, food security and human nutrition are generated and strategies for future research are suggested calling for integration of agriculture, ecology, nutrition, and socio-economics.

1. Introduction
While great strides in reducing hunger through increases in agricultural productivity have been made worldwide, more than 900 million people are undernourished (FAO, 2010), over 2 billion people are afflicted by one or more micronutrient deficiencies (WHO, 2007) and over 1 billion adults are overweight (WHO, 2003). In addition to producing sufficient calories, a major, often overlooked challenge in agriculture and food systems is to provide an adequate diversity of nutrients necessary for a healthy life. A human diet requires at least 51 nutrients in adequate amounts consistently (Graham *et al.*, 2007). It has been argued that changes in agricultural production systems from diversified cropping systems towards ecologically more simple cereal-based systems have contributed to poor diet diversity, micronutrient deficiencies and resulting malnutrition in the developed as well as developing world (Graham *et al.*, 2007; Frison *et al.*, 2006; Negin *et al.*, 2009; Welch and Graham, 1999). Success of agricultural systems has historically been evaluated primarily on metrics of crop yields, economic output and cost-benefit ratios (IAASTD, 2009). Yet, these metrics do not reflect the diversity of nutrients provided by the system that is critical for human health. In this study we take a step to demonstrate how ecological tools can play a role in addressing nutritional diversity as an overlooked ecosystem service of agricultural systems.

In nutritional sciences, several methods have been developed that look beyond the single nutrient or food item to capture the broader picture of diet diversity (FAO-FANTA, 2008; Drescher *et al.*, 2007; Waijers *et al.*, 2007; Rose *et al.*, 2008; Kennedy *et al.*, 2010). Count measures are frequently applied to assess diet diversity, where the number of consumed food items and food groups is recorded (FAO-FANTA, 2008). Diet quality indices have also been developed that take into account consumption pattern and nutritional composition of food items

(Drescher *et al.*, 2007; Waijers *et al.*, 2007). Numerous studies have shown that nutritional quality of the diet improves as a higher diversity of food items or food groups is consumed (Shimbo *et al.*, 1994; Hatloy *et al.*, 1998; Moursi *et al.*, 2008; Steyn *et al.,* 2006; Kennedy *et al.*, 2005) and increased diet diversity has been associated with positive health outcomes such as lower rates of stunting, mortality and incidence of cancer (Arimond and Ruel, 2004; IFPRI, 1998; Kant *et al.*, 1993; Slattery *et al.*, 1998; Levi *et al.*, 1998; Bhutta *et al.*, 2008).

Approaches to quantifying diet diversity in nutrition research have direct analogues to approaches to quantifying biological diversity in ecology. Counting total number of food items or food groups is analogous to counting species richness and functional group richness. In ecology, there is increasing interest in quantitative measures of functional diversity, which take advantage of the wealth of information available on species' traits, particularly for plants, to overcome some of the drawbacks or lack of sensitivity of the simpler measures of diversity (Diaz and Cabido, 2001). Among these quantitative approaches is the functional diversity metric FD (Petchey and Gaston, 2002). FD is a metric that reflects the trait distinctiveness of a community and the degree of complementarity in traits of species within a community.

Here we explore a novel nutritional functional diversity metric (nutritional FD). The nutritional FD metric is based on plant species composition on farm and the nutritional composition of these plants for 17 nutrients that are key in human diets and for which reliable plant composition data are available (Table 1). We use this FD metric to summarize and compare the diversity of nutrients provided by farms in three sites in sub-Saharan Africa (SSA).

The nutritional FD value increases when a species with a unique combination of nutrients is added to a community, and decreases when such a species is lost. Changes in the presence or absence of species with identical nutritional composition do not change the value of FD, however such redundancy provides a buffer, in case other species are lost from the system. For example, changing climate conditions could prevent some plant species from being successfully cultivated, so having several species with similar nutritional composition means that such a shift in crop species composition would not necessarily impact the overall nutritional diversity at the farm or community level. The nutritional FD metric thus reflects the diversity of nutrients provided by the farm and the complementarity in nutrients among species on a farm or community.

Table 1. Nutrients and nutrient groups taken into account for calculation of FD metrics.

Macronutrients	Minerals	Vitamins
Protein	Calcium (Ca)	Vitamin A
Carbohydrates	Iron (Fe)	Vitamin C
Dietary fibre	Potassium (K)	Thiamin
Fat	Magnesium (Mg)	Riboflavin
	Manganese (Mn)	Folate
	Zinc (Zn)	Niacin
	Sulphur (S)	

From the 51 required nutrients for human diets, 17 nutrients that are key for human diets and for which reliable plant composition data were available in the literature were selected. Because plants are not a proven source for vitamin B12 and vitamin D, these were not included.

The three sites examined here, Mwandama in Malawi, Sauri in Kenya, and Ruhiira in Uganda, are part of the Millennium Villages Project (MVP), where food insecurity and undernutrition rates are high (Sanchez *et al.*, 2007; MVP, 2010; Nziguheba *et al.*, 2010). A principal goal of the MVP is to improve food security and nutrition through a set of interventions recommended by the United Nations Millennium Project Hunger Task Force (UN Millennium Project, 2005). The sites represent distinct but representative agro-ecosystems of SSA (Table 2), with maize (Mwandama, Sauri) or banana (Ruhiira) as the staple crop. Subsistence farming is the main livelihood strategy for over 75 percent of the households in these sites (Sanchez *et al.*, 2007; MVP, 2010; Nziguheba *et al.*, 2010). On average 50 percent of food consumed in the household comes from own production and 75 percent of food consumed in the village comes from production within the village (Table 2).

In this study we explore how nutritional FD metrics can provide insights in nutrient diversity of farming systems and can have potential to guide agricultural management. Data on plant species diversity, food security and diet diversity were collected for plots and home gardens of 170 farms in Mwandama, Sauri and Ruhiira and iron and vitamin A deficiency was determined from blood samples for 30 adult women per village. Four nutritional FD metrics were calculated: FDtotal describing diversity for all 17 nutrients of Table 1, FDmacronutrients for the four macronutrients, FDminerals for the seven minerals and FDvitamins for the six vitamins. Differences between farms and villages for species richness, nutritional FD, household food and health indicators were analysed as well as relationships between these different indicators.

Table 2. Site characteristics.

	Malawi, Mwandama	**Kenya, Sauri**	**Uganda, Ruhiira**
Farming system and Agro-ecological zone	Cereal root-crops mixed Subhumid Tropical	Maize mixed Subhumid tropical	Banana-based Highland perenial
Major crops	Maize	Maize, Beans	Banana
Rainfall pattern and annual average (mm)	Unimodal 1139	Bimodal 1800	Bimodal 1050
Altitude (m above sea level)	900-1200	1400	1350 - 1850
Average area cropped per household (ha)	1.0	0.6	1.9
Average % of food consumed by the household that comes from own production (calculated in $ values)	46%	35%	69%
Average % of food consumed in the village that comes from production in the village (calculated in $ values)	70%	75%	82%
Dominant soils and fertility conditions loam	Rhodustalfs, loamy to clayey	Rhodic Hapludox, clayey	Rhodic Hapludox and Acrisols, sandy clay
Soil pH	5.25 (± 0.60)	5.74 (± 0.37)	5.45 (± 0.85)
Soil Effective Cation Exchange Capacity (ECEC)	5.74 (± 2.34)	7.03 (± 1.96)	13.63 (± 4.34)
Soil % Nitrogen (N)	0.079 (± 0.026)	0.121 (±0.031)	0.260 (± 0.066)
Soil % Carbon (C)	1.098 (± 0.415)	1.461 (±0.332)	3.078 (± 0.742)
Soil C/N ratio	13.91 (± 2.18)	12.39 (±2.20)	11.96 (± 1.27)

Soil values represent average scores ± standard deviation based on 60 samples [29, 65]

2. Methods

2.1 Research sites

The Mwandama village cluster is located in the southern Zomba district of Malawi and covers an approximate population of 35 000 people. The region once characterized by native Miombo woodlands is now intensively cultivated. Smallholders grow mainly maize, pigeon peas, cassava and groundnuts, while commercial estates produce tobacco and maize. Livestock management is practised on a small scale and is restricted to chicken and goats.

The Sauri cluster is located in the Kenyan highlands in the western Nyanza Province and has a farm community of 63 500 people. The main occupations are subsistence farming, consisting primarily of maize, sorghum and cassava, and animal husbandry, including goats, chickens and cattle.

The Ruhiira cluster is situated in the Isingiro district in the hilly, dissected terrain of southwest Uganda and has a population of approximately 43 056 people. The agricultural system is predominantly a mixed system with livestock and cultivation of annual and perennial crops. The main crop is banana, which covers approximately 30 percent of the total cropland.

Further site characteristics are outlined in Table 2 (Sanchez *et al.*, 2007; MVP, 2010; Nziguheba *et al.*, 2010).

2.2 Sample selection and data collection

A random sample of 50 to 60 farms per site was selected based on demographic and geographic MVP data for 300 previously randomly selected households per cluster. For Ruhiira and Mwandama data for 60 farms were collected during June–September of 2009. For Sauri data for 50 farms were collected during November of 2009. The study procedures, purpose, risks and benefits were explained to participants during the informed consent process. The study received ethical approval from the Institutional Review Board at Columbia University.

2.3 Documentation of species diversity

For each of the 170 farms, all plots, including home gardens, cultivated by the household, were sampled to document all crop, plant and tree species, with different species and varieties according to local definitions. Plant species were confirmed with the help of local botany studies (Maundu *et al.*, 1999; Maundu *et al.*, 2005; Chewya and Eyzaguirre, 1999; Smith and Eyzaguirre, 2007; NRC, 1996, 2006, 2008). In addition, it was noted if these plants were edible and consumed by the household. Only plants that were edible and consumed in the village were considered for this study.

2.4 Nutritional trait data of plants

A database of plant nutritional composition data was developed based on existing studies and databases. When different parts of certain plants were consumed, both parts were listed and taken into account in further calculations. The nutritional composition data were standardized and weighted by converting values to the percentage of the Dietary Reference Intake (DRI) (NAS, 2009) for the specific nutrient provided by 100 g of the consumable product. So, for each nutrient, percentage of DRI provided by 100 g of that plant species were the values used to calculate the FD scores. Seventeen nutrients were selected based on data availability and the essential role they play in human diets (Table 1).

2.5 Calculation of diversity metrics

Species richness was defined by the number of identified and previously described edible species per farm. Petchey and Gaston's FD (Petchey and Gaston, 2002) was used as a measure of nutritional functional diversity, with 17 nutrients from 77 crops (Figure 1).
Functional diversity metrics begin with two data matrices: 1) a species by trait matrix, and 2) a farm or site by species matrix (Petchey *et al.*, 2009). In the method

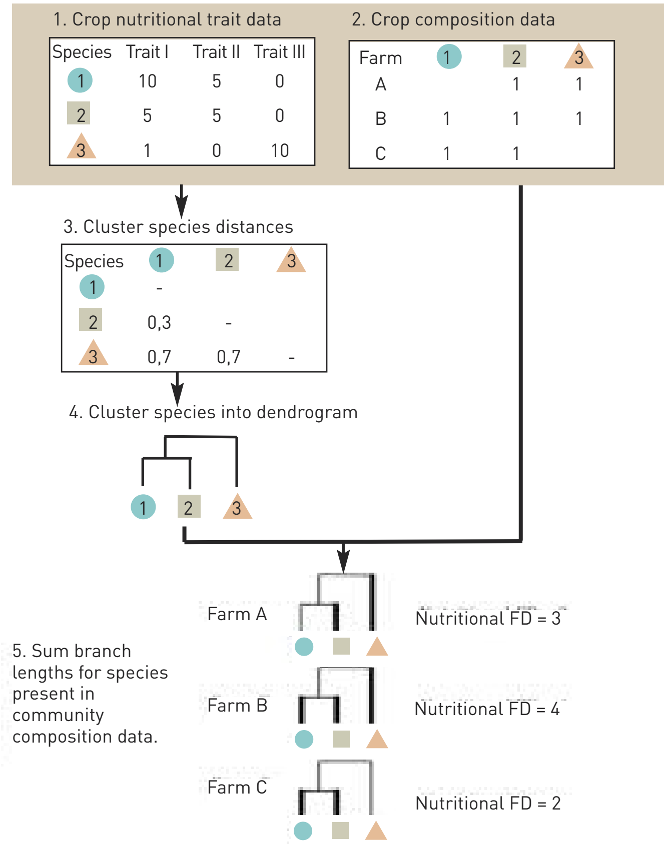

Figure 1. Schematic model of how to assess nutritional functional diversity.
Two data sets are required: a species by trait matrix (1), and a farm or site by species matrix (2). From the species x trait matrix, the multivariate distances between crop species are calculated (3), where distance is a function of distinctness in nutrient composition and content. The distances between species are used to cluster species into a dendrogram (4). Based on the crop species present in a given farm, the branch lengths of the dendrogram are summed (5). Example Farms A and C illustrate how nutritional functional diversity can differ even when species richness is identical, depending on the nutritional distinctiveness of the crop species present.

we used here, the species x trait matrix is used to calculate the multivariate distances between crop species, where distance between a pair of species determined by the distinctness in nutrient composition and content. Then the distances between species are used to cluster species into a dendrogram, which reduces the dimensionality of the diversity metric calculation. Finally, based on the crop species present in a given farm, the branch lengths of the dendrogram are summed, to give the FD value (Figure 1).

In the crop nutritional data set we use here, the species x trait matrix is composed by the percentage of DRI for a specific nutrient. The community composition matrix contains the presence or absence of each crop species for each of the 170 farms. We calculated nutritional FD in four ways: using all 17 nutrients, using just the four macronutrients, using the six vitamins, and using the seven minerals (Table 1), resulting in four respective FD metrics: FDtotal, FD-macronutrients, FDminerals and FDvitamins. Results were scaled by the maximum values to range from 0 to 100 for each FD metric separately.

2.6 Functional redundancy and observed versus expected FD

We assessed the degree of functional redundancy by simulations that model observed versus expected functional diversity for a given species richness (Figure 2) (Flynn *et al.*, 2009).

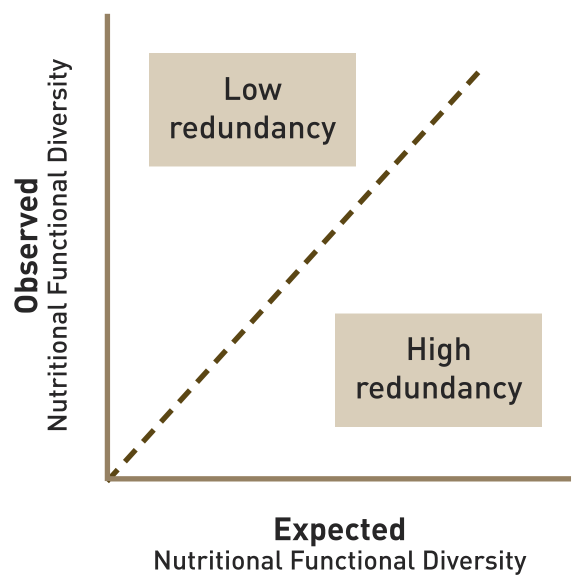

Figure 2. Schematic model to assess degree of redundancy by modelling observed versus expected functional diversity for a given species richness.
If a set of communities has a large range of species richness, but shows little variation in functional diversity, then the species pool in that set of communities has high functional redundancy. In contrast, a set of communities with low functional redundancy may exhibit large changes in functional diversity with only small changes in species richness.

To calculate "expected FD" scores, we used a simulation approach to create a null distribution of FD values for the observed number of species. Holding species richness constant for each of the 170 households, we randomly selected species without replacement from the species pool (the total number of species in the study) to calculate a null FD value for each household. We repeated this 5 000 times to produce a distribution of null values and tested whether the observed FD for each household was significantly higher or lower than the null FD distribution, at $\alpha = 0.05$ (Flynn *et al.*, 2009). For this study, "expected FD" is thus the mean of the functional diversity calculated from many possible species combinations for a particular number of species.

This approach allows us to determine if changes in FD across households simply reflect species richness, or if species composition and trait diversity vary in other ways, e.g. with village or other factors. If a set of communities has a large range of species richness, but shows little variation in functional diversity, then the species pool in that set of communities has high functional redundancy (Figure 2). That is to say, many species share similar traits and the loss of a few species has little impact on functional diversity. In contrast, a set of communities with low functional redundancy may exhibit large changes in functional diversity with only small changes in species richness (Figure 2) (Flynn *et al.*, 2009).

2.7 Household food indicators

Recommendations of the Food and Nutrition Technical Assistance (FANTA) project were used to develop questionnaires for the months of inadequate household food provisioning (MIHFP, range 0–12; adapted from months of adequate household food provisioning (Bilinsky and Swindale, 2007), household food insecurity access scale (HFIAS, range 0–21) (Coates *et al.*, 2007) and household diet diversity score (HDDS, range 0–15) (FAO-FANTA, 2008) based on a 24-hour recall for consumption of 15 food groups: cereals; vitamin A rich vegetables and tubers; white tubers, roots and plantains; green leafy vegetables; other vegetables; vitamin A rich fruits; other fruits; legumes and nuts; oils and fat; meat; fish; eggs; milk; sweets; spices and tea (FAO-FANTA, 2008). The surveys were first pre-tested and adapted to local conditions and language.

2.8 Iron and vitamin A deficiency

Individual serum samples were collected from 30 women between the ages of 13 and 49 per site (90 in total) to determine iron and vitamin A deficiency.

Iron was measured by a colorimetric assay using the Hitachi 917 analyser (Roche Diagnostics, Indianapolis, IN). Under acidic conditions, iron is liberated from transferrin. Ascorbate reduces the $Fe3+$ ions to $Fe2+$ ions, which then react with FerroZine re-agent to form a coloured complex. The colour intensity is directly proportional to the iron concentration in the sample and is measured photometrically. Iron at the concentration of 46, 93 and 138 ug/dL has a day-to-day variability of 1.8%, 1.1% and 0.6%, respectively. Iron deficiency was defined as a level less than 15 ng/mL (FAO-WHO, 1988). The levels of vitamin A were measured by high performance liquid chromatography (Shimadzu Corporation, Kyoto, Japan). Vitamin A is de-proteinized from the serum/plasma sample using ethanol and extracted with hexane. The extract is dried, re-dissolved with ethanol and injected into the chromatograph. Retinyl acetate is used as the internal standard. This assay is standardized using calibrators from the National Institute of Standards and Technology. The minimum required volume for this assay is 150 microlitres. Vitamin A deficiency was defined as a level $\leftarrow$ 20 micrograms/dL (FAO-WHO, 1988).

All calculations, as well as general linear models and analysis of variance, were done in the statistical programming environment R (2.11.0, www.r-project.org).

Table 3. Indicator outcomes per site

		Malawi, Mwandama	Kenya, Sauri	Uganda, Ruhiira	p-value
Edible plant diversity in village	Edible species richness of village (number of unique species for that site)	42 (11)	49 (11)	55 (13)	
Edible plant diversity per household farm	Edible species richness	11.15 ± 3.66	15.22 ± 4.29	18.25 ± 4.82	←0.001
	Nutritional FDall [0–100]	49.25 ± 17.96	64.56 ± 16.32	68.44 ± 15.82	←0.001
	Nutritional FDmacronutrients [0–100]	46.73 ± 9.75	52.7 ± 13.15	72.23 ± 14.54	←0.001
	Nutritional FDminerals [0–100]	32.21 ± 10.56	52.52 ± 16.14	70.88 ± 16.2	←0.001
	Nutritional FD vitamins [0–100]	41.97 ± 24.48	46.91 ± 17.92	45.78 ± 18.08	0.41
Household food indicators	HHDDS	7.57 ± 2.58	8.22 ± 2.05	9.2 ± 3.18	←0.001
	HHFIS	11.65 ± 5.80	7.62 ± 5.01	10.27 ± 4.96	←0.001
	MIHFS	4.37 ± 2.27	2.56 ± 2.18	3.97 ± 1.67	←0.001
Nutritional health indicators	Vit A deficiency women	0.00%	3.30%	6.70%	0.563
	Fe deficiency women	23.30%	6.70%	6.70%	←0.001

Values represent total number for indicators at the village level and average scores for indicators at the household (= farm) or individual level ± standard deviation. P-values are shown for ANOVA test of village effect on farm/household/individual level indicators. HHDDS: Household Diet Diversity Score; FIS: Household Food Insecurity Score, MIHFS: Months of Inadequate Household Food Supply.

3. Results

3.1 Species diversity

Across the 170 farms of the three sites, a total of 77 edible, previously described plant species were identified. Twenty-seven of these 77 species were common among all three sites. The average number of edible species per farm differs significantly between villages, ranging from 11 in Mwandama to 18 in Ruhiira (Table 3).

Farm species richness was found to be independent from farm landholding size (r2 = -0.0017, p = 0.366), also when corrected for village. The five most commonly grown crops across all three sites are bananas (on 93% of the farms), maize (91%), beans (75%), cassava (75%) and mango (69%). Examples of unique species for one of the sites include several green leafy vegetables such as *Corchorus olitorius* (apoth) and *Crotalaria brevidens* (mito) for Sauri in Kenya; tamarillo or tree tomato (*Solanum betaceum*) and some spices, e.g. ginger and cardamom, for Ruhiira in Uganda; certain fruits such as peaches, figs and pomegranates for Mwandama in Malawi.

3.2 Nutritional FD and relationship with species richness

Four nutritional FD metrics (FDtotal, FDmacronutrients, FDminerals and FDvitamins) were calculated for each of the 170 farms (Table 3). This approach allows us to investigate the nutritional diversity across all nutrients and within each of the major nutrient groups. For three out of these four FD metrics, average values for farms differ significantly between the sites (p←0.001) (Table 3), with equivalent values only for FDvitamins (p=0.41). Similar to species richness, all FD metrics were found to be independent from farm landholding size (p→0.1).

Figure 3 plots FD values against species richness for each of the 170 farms.

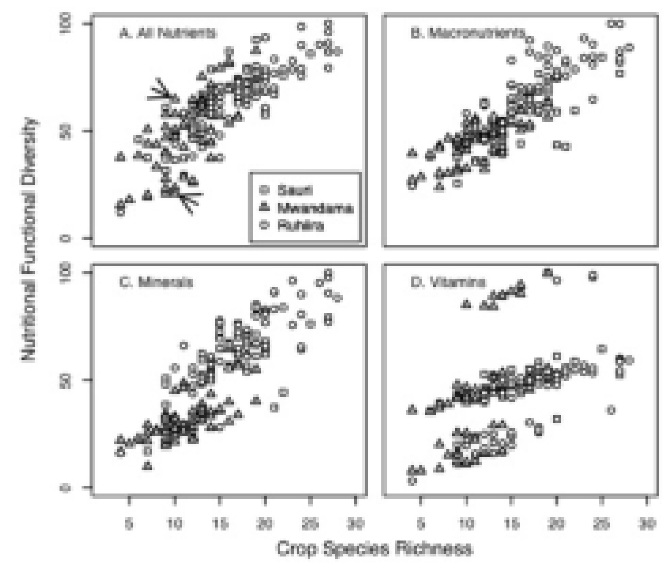

Figure 3. Nutritional functional diversity values are plotted against species richness for 170 household farms.
A: Nutritional FD = FDtotal, summarizing functional diversity for all 17 nutrients listed in Table 1; B: Nutritional FD = FD-macronutrients for the four macronutrients; C: Nutritional FD = FDminerals for the seven minerals; D: Nutritional FD = FDvitamins for the six vitamins (Table 1). Farms in Mwandama are shown as triangles, farms in Sauri as squares, and farms in Ruhiira as circles.

Regression of FDtotal (Figure 3A) against species richness reveals several patterns. First is a strong positive correlation ($p \leftarrow 0.001$; $r2=0.68$) between FD-total and species richness, independent of village. Thus, as the number of edible species increases, the diversity of nutrients that farm provides also increases. Second, at a level of around 25 species per farm, the relationship between FDtotal and species richness starts levelling off, meaning that additional species to a farm, with around 25 or more species, increases nutritional diversity very little. Third, although species richness and FDtotal are correlated, farms with the same number of species can have very different nutritional FD scores.

For example, two farms in Mwandama (indicated by arrows on Figure 3A) both with 10 species show an FDtotal of 23 and 64, respectively. The difference in FD is linked to a few differences in species nutritional traits. Both of these example farms grow maize, cassava, beans, banana, papaya, pigeon pea and mango. In addition, the farm with the higher FD score grows pumpkin, mulberry and groundnut, while the farm with lower FD score has avocado, peaches and black jack (in Malawi, black jack leaves are consumed). Trait analysis shows that pumpkin (including pumpkin leaves, fruits and seeds which are all eaten) adds diversity to the system by its relatively high nutritional content in vitamin A, Zn and S-containing amino acids (methionine and cysteine) compared to other species; mulberry by its levels of vitamin B complexes (thiamin, riboflavin) and groundnut by its nutritional content for fat, Mn and S. The black jack, avocado and peaches found in the lower FD farm add less nutritional diversity to the system than pumpkin, mulberry and groundnut since they do not contain the vitamin B or S complexes, and thus are less complementary to the other plants in the system for their nutritional content. This example shows how different crop species compositions can result in very disparate nutritional FD even with identical numbers of crops planted in a field.

When considering the FD values based on the nutrient subgroups, i.e. macronutrients, minerals and vitamins, the pattern of the relationship between species richness and FD differs among subgroups (Figure 3B, C and D).

While FDmacronutrients increases nearly linearly with increasing species richness, FDvitamins shows abrupt changes and is highly dependent on the presence of few species. For example, addition of mulberry or guava species strongly increases the FDvitamins value of the farm because of their unique high values for vitamin B complexes and vitamin C, respectively. This uniqueness attributed to a few key species results in a stepwise pattern of different FDvitamins levels instead of a gradual increase with number of species and indicates high species sensitivity (see also below). For FDminerals, the group of farms in Mwandama differs significantly from the Ruhiira and Sauri farms, by lower FDminerals values and a lower slope in the FDminerals – species richness relationship (p<0.001). This suggests that the species on the Mwandama farms are not contributing as much mineral diversity to the system as species in the Kenya or Uganda village (see also below).

3.3 Functional redundancy

A crucial component of FD is functional redundancy (Petchey *et al.*, 2007), which reflects the degree of overlap in the traits of species in a community. We assessed the degree of functional redundancy by simulations that model observed versus expected functional diversity for each of the 170 farms and the four nutritional FD metrics (Figure 4).

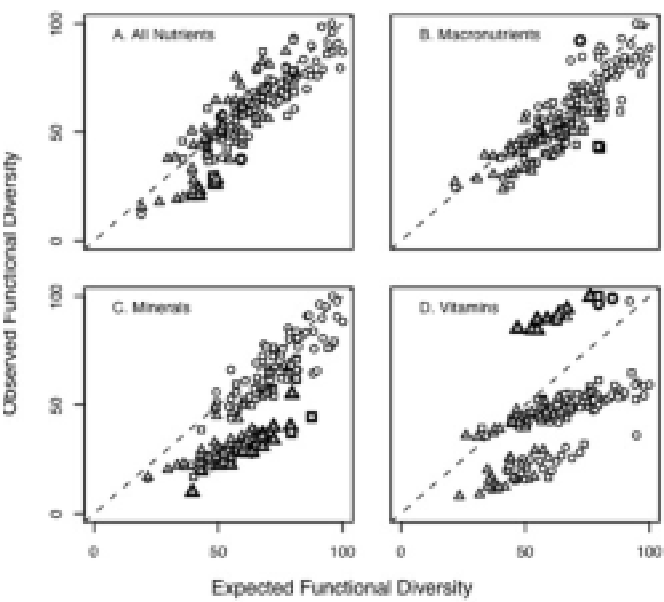

Figure 4. Observed values for nutritional diversity are plotted against simulated expected nutritional FD values for 170 household farms.
Farms that have observed FD values significantly different from expected FD values are marked in bold. Farms in Mwandama are shown as triangles, farms in Sauri as squares, and farms in Ruhiira as circles.

When observed FD is higher than expected, it indicates low functional redundancy, or that species are more distinct from one another than expected by chance (Figure 2) (Flynn *et al.*, 2009).

Figure 4 illustrates that functional redundancy patterns differ among nutrient groups. For FDtotal and FDmacronutrients no strong redundancy patterns are observed (Figure 4A, B). For FDminerals, a group of farms (in bold in Figure 3C) with an observed FD significantly lower (at α=0.05) than the expected FD was identified, meaning there is high functional redundancy, with several species having similar nutrient traits. Most of these farms are of the Mwandama site, and in contrast to other farms, they are entirely lacking a set of species identified as most influential for mineral diversity including *Sesamum calycinum* (onyulo) which is particularly rich in Fe, *Eleusine coracana* (finger millet) with high Ca and Mn levels, *Glycine max* (soybean) rich in Fe, Mg and Mn, *Helianthus anuus* (sunflower) which seeds have high levels of Zn, Mg and S, and *Solanum nigrum* (black nightshade) rich in Fe and Mn.

In contrast to the pattern of high redundancy for FDminerals, for FDvitamins a group of farms (in bold in Figure 4D) can be identified with significantly higher observed FD than expected FD, meaning there is low functional redundancy on those farms as only a few species provide certain combinations of vitamins (Figure 4D). What these farms have in common is that they all contain the species *Morus alba* (mulberry). As mentioned above, mulberry, especially the leaves, contain vitamins B complex and C, in higher levels than most other plants. Addition or loss of mulberry as one of the few species in the community providing vitamin B complex, can increase or reduce FDvitamins significantly.

3.4 Linking to food and health indicators

In addition to agrobiodiversity data, data on household food indicators including a household food insecurity access scale (HFIAS), number of months of inadequate household food provisioning (MIHFP) and household diet diversity scores (HHDDS) were obtained for each of the 170 farms (Table 3). Significant differences between villages for these indicators reflect different levels in food security and diet diversity, with lower food security and diet diversity in Mwandama as compared to Ruhiira and Sauri (Table 3). Average village data indicate that low species richness and FD scores at the village level are paired with low diet diversity, high food insecurity and number of months of inadequate food provision of the village community (Table 3).

Analysis of correlations between these household food indicators and farm species richness and nutritional FD metrics indicate that for each of the food indicators, correlation coefficients are slightly higher for FD metrics than for species richness. But none of these correlations are significant and significance does not change when corrected for village and/or land size (data not shown).

The patterns for iron and vitamin A deficiencies at the village level (Table 3) are similar to patterns for FDminerals and FDvitamins respectively: while Mwandama shows significantly higher rates of Fe deficiency than Ruhiira and Sauri, average FDminerals of Mwandama farms is significantly lower compared to FDminerals in Ruhiira and Sauri. No significant differences between sites are found for vitamin A deficiency and similarly, FDvitamins is the only FD metric for which the three sites score equally.

4. Discussion

Sub-Saharan Africa faces pressing challenges, with 40 percent of children chronically undernourished or stunted (UNICEF, 2009). As new investments and attention galvanize much-needed action on African agriculture, a vigorous debate is required to ensure that agricultural progress is evaluated based on metrics that go beyond economic cost/benefit ratios and calories per person and that can also address the complexity of nutritional diversity required for human health. In this study, we demonstrate how an ecological concept, the FD metric, has potential to summarize nutritional diversity of cropping systems and thereby provide new insights on provisioning ecosystem services across farms and villages in sub-Sahara, Africa.

The strengths of the study lie in the development of a systems approach that is able to consider the large variety of species available in the system together with their nutritional composition and in the step it takes towards integrating agriculture, nutrition and ecology studies (Deckelbaum *et al.*, 2006; Remans *et al.*, 2011). By applying the FD metric on nutritional diversity, it was possible to identify variability in nutritional diversity across farms and villages (e.g. low diversity for minerals in the Mwandama cluster compared to Sauri and Ruhiira) as well as to identify species that are critical for ensuring the provisioning of certain nutrients (e.g. mulberry for vitamin B complexes). The results also emphasize that the species nutritional composition and redundancy available in the system determine if introduction or removal of certain species will have critical impacts on the nutritional diversity of the community (e.g. addition of species to farms with around 20 species does not cause much change to FDtotal, high species sensitivity for FDvitamins, high redundancy for FDminerals).

While in the past, food-based interventions in developing countries have focused mostly on a single nutrient (Frison *et al.*, 2006), the approach described in this study can help guide agricultural interventions towards diversity of nutrients and/or towards nutrient redundancy or resilience of the system. In particular, this work provides means to identify potential crops, varieties or groups of plants that add nutritional value (diversity or redundancy) and can be introduced, promoted or conserved taking into account the functional diversity of species already available in the system. The single nutrient approach of the past, varying from various recommendations for high-protein diets (Brock *et al.*, 1955) and later for high-carbohydrate diets (McLaren, 1966, 1974), to more recent efforts directed at the elimination of micronutrient deficiencies, was in part linked to a lack of knowledge in earlier years about the interactions among nutrients in human physiology and metabolism (Frison *et al.*, 2006). The roles of micronutrients in health and well-being and the synergies in their physiologic functions are now being increasingly recognized, supporting the notion that nutrient deficiencies rarely occur in isolation and calling for dietary diversification (Frison *et al.*, 2006; Latham, 2010; McLean *et al.*, 2009). These advances in nutritional sciences also create a demand for applying a more holistic approach to the nutritional diversity of agricultural systems as described here.

This study is, however, limited and offers room for improvement on several fronts. First, no data were collected on the quantities produced or on species evenness. Cropping area or yield data would further strengthen the study by allowing calculation of an abundance-weighted FD metric, several of which have been developed in community ecology (Mouchet *et al.*, 2010; Laliberté and Legendre, 2010). While this is planned as a next step in future work, presence/absence-based FD metrics are valuable as predictors of ecosystem functioning (Flynn *et al.*, 2011). The nutritional FD metric of this study gives thereby valuable insights on the diversity of nutrients provided by the cropping system, particularly on the complementarity and redundance of species in the system and on the potential of species to contribute nutritional traits to the existing composition of species (on farm or in the village).

Second, the nutritional composition data and FD metric calculations were based on available species level data. It is known that a large diversity in nutritional composition exists among different varieties of species as well as among different environments in which plants are cultivated (Bates, 1971; Kennedy and Burlingame, 2003; Davey *et al.*, 2009). For example, certain varieties of *Phaseolus vulgaris* L. (common bean) are significantly higher in iron and zinc than other *P. vulgaris* varieties (Graham *et al.*, 2007; Blair *et al.*, 2010), and addition of zinc fertilizer to the soil can further increase the concentration of trace elements in edible parts (Graham, 2008). Also, the FD calculation used here does not take into account the level of neutriceuticals and phytochemicals, that play a beneficial role for human health, nor the level of antinutritional factors (e.g. phytate, oxalate, tannins) that reduce the bioavailability of certain nutrients (e.g. Ca, Fe, proteins). Efforts to acquire more data at the species and subspecies level on nutritional composition across different environments, will allow fine-tuning of the proposed FD metrics. In addition, including livestock diversity and number will provide a more complete picture of the nutritional diversity available on farm.

No significant correlations at the farm level were found between nutritional FD of crops grown and household food consumption indicators. This might be partly due to limitations of the proposed FD metrics or the relatively simple household food indicators used in this study, but also to the complex pathway between agricultural production and food consumption (World Bank, 2007; Rose *et al.*, 2009). While most households in the studied villages are considered subsistence farmers, farm households are not closed systems.

Food consumption and expenditure data (Table 2) show that the average proportion of food consumed coming from own production is around 50 percent. Also, a significant correlation was found between the number and value of food items bought and sold on local markets and the household food indicators at each of the three sites (FIS, HHDDS, MHIFS) (Lambrecht, 2009). These findings emphasize the importance of local markets and support the notion that these farm households are not closed systems. The most appropriate scale to link nutritional FD metrics to food consumption and nutrition indicators, would be the "foodshed", defined as the geographic area that supplies a population centre with food (Peters *et al.*, 2008). Village level data show that for example for Ruhiira 82 percent of food consumed is derived from production within the village

(Table 2). This indicates that in the case of these villages, the foodshed, largely overlaps with the village. It is therefore interesting to note that certain associations between nutritional FD and food and nutrition indicators were observed at the village level: the correspondence in patterns between FD-minerals and Fe deficiency, FDvitamins and vitamin A deficiency and FDtotal and diet diversity, food insecurity and number of months of insufficient food supply. These findings generate new hypotheses on the link between nutritional diversity of the farming system and nutrition outcomes at the village or in particular the foodshed level such as: Can the high rate of Fe deficiency among adult women in Mwandama be due partly to a lack of species that contribute more significantly to mineral diversity, particularly those high in Fe? Also, does the high crop species richness in Sauri and Ruhiira play a role in their relatively lower level of food insecurity? In addition, the study triggers new questions as to what are the determinants or filters of nutritional diversity on farms, villages and agro-ecological zones. For example, it is clear that mineral diversity of species in the Mwandama village is lower than in Sauri and Ruhiira, and even when species richness increases, FDminerals in Mwandama remains relatively low. Several potential barriers for growing species that add more to FDminerals can be hypothesized and could be categorized under ecological (e.g. climate, soil, altitude, water availability), dispersal (large distance to origin of seeds) or anthropogenic determinants (e.g. cultural preference, limited economic access to seeds, lack of knowledge). In this context, it is interesting to note that soil fertility measures in the Mwandama village (Table 2) show very low values for effective cation

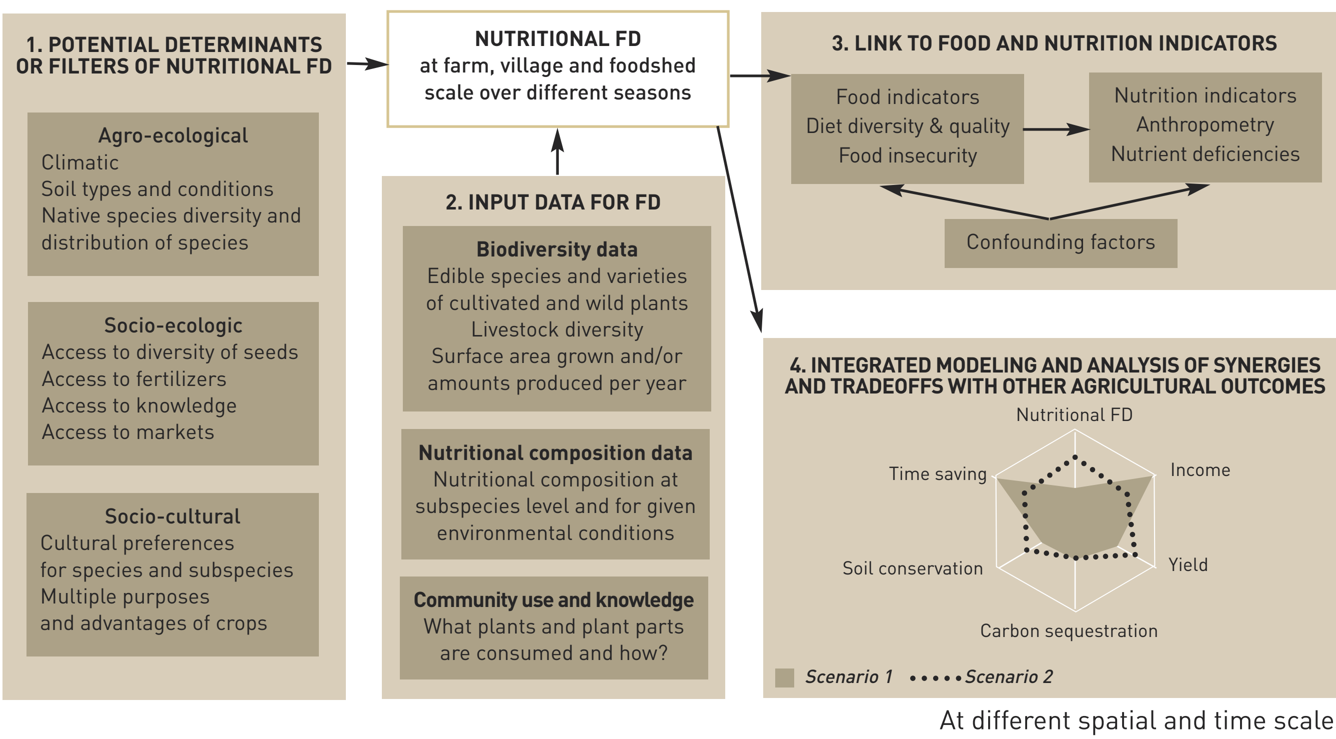

Figure 5. Suggested strategy for future research on nutritional functional diversity.
The overall objective of the strategy is to guide agricultural and landscape interventions towards more balanced nutritional outcomes. Three major fronts for research are suggested: study of potential determinants and barriers of nutritional FD and identify the ones that can be controlled (1); collection of new and mobilization of existing data that enable a more comprehensive calculation of nutritional FD and this at a landscape and village level (2); establishing linkages with consumption and human health outcomes of agricultural systems through integrated data sets that include health and socio-economics (3); and integrated modelling and analysis of potential synergies and trade-offs between nutritional diversity and other outcomes from agriculture (4).

exchange capacity (ECEC) and percentage of total nitrogen (N), two factors that are critical for soil fertility. It can be hypothesized that the soil conditions in Mwandama restrict successful cultivation of crops to only those adapted to lower soil fertility conditions or it might be that farmers' preference for certain crops or soil management strategy has impacted soil fertility over time.

Based on the findings and new questions raised, a strategy for future research is outlined in Figure 5, with an overall objective to guide more balanced nutritional outcomes from agricultural systems.

The strategy emphasizes four major fronts for expanding the research presented here: 1) study on potential determinants and barriers of nutritional FD in different settings; 2) collection of new and mobilization of existing data that enable a more comprehensive calculation of nutritional FD across different villages; 3) establishing linkages between nutritional diversity of farming systems and consumption and human health outcomes, particularly at the foodshed scale (Peters *et al.*, 2008; Niles and Roff, 2008); and 4) integrated modelling and analysis of potential synergies and trade-offs between nutritional diversity and other outcomes from agriculture, e.g. income generation, risk reduction, greenhouse gas emissions, water quality, labour intensity and social well-being. Such modelling can be done at different scales (farm, village, country, region, global) and across agro-ecological zones to identify how complementary different agro-ecosystems are for providing the necessary nutritional diversity.

In conclusion, this study delivers novel work on addressing nutritional diversity of agricultural systems. We show that applying the ecological functional diversity metric on nutritional traits of plants in agricultural systems gives insights on the diversity of nutrients provided by cropping systems. Application of this metric can help guiding management decisions towards increased nutrient diversity for a given number of species, as well as towards increased redundancy or buffer of species for a specific set of nutrients.

In addition, new hypotheses on the link between agrobiodiversity and nutrition are generated and a cross-disciplinary research framework is suggested. Nutritional FD is thereby a tool that bridges agriculture, human nutrition and ecology studies and offers an entry point for integration of other scientific disciplines (economics, anthropology, human health, landscape ecology) (Remans *et al.*, 2011; Rumbaitis del Rio *et al.*, 2005; DeClerck *et al.*, 2006). Assessing the multiple outcomes of agricultural systems across agro-ecological zones is critical for making progress towards more sustainable and nutritious food systems (Sachs *et al.*, 2010).

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References

Arimond M, Ruel MT (2004) Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. J Nutr 134: 2579-2585.

Bates TE (1971) Factors affecting critical nutrient concentrations in plants and their evaluation: A review. Soil Science 112: 116-130.

Bhutta ZA, Ahmed T, Black RE, Cousens S, Dewey K, et al. (2008) What works? Interventions for maternal and child undernutrition and survival. Lancet 371:417-40.

Bilinsky P, Swindale A (2007). Months of Adequate Household Food Provisioning (MAHFP) for Measurement of Household Food Access: Indicator Guide. Food and Nutrition Technical Assistance Project, Academy for Educational Development. Washington, D.C.

Blair MW, González LF, Kimani PM, Butare L (2010) Genetic diversity, inter-gene pool introgression and nutritional quality of common beans (Phaseolus vulgaris L.) from Central Africa. Theoret Appl Genetics 121: 237-248.

Brock JF, Hansen JDL, Howe EE, Pretorius PD, Daval JGA, Hendricks RG (1955) Kwashiorkor and protein malnutrition. A dietary therapeutic trial. Lancet 2: 355–60.

Chewya JA, Eyzaguirre P (1999) The biodiversity of traditional leafy vegetables. IPGRI, Rome.

Coates J, Swindale A, Bilinsky P (2007) Household Food Insecurity Access Scale (HFIAS) for measurement of Food Access: Indicator Guide (v. 3). Food and Nutrition Technical Assistance Project, Academy for Educational Development, Washington, D.C.

Davey MW, Saeys W, Hof E, Ramon H, Swennen R, et al. (2009) Application of visible and near-infrared reflectance spectroscopy (Vis/NIRS) to determine carotenoid contents in banana (Musa spp.) fruit pulp. J Agric Food Chem 57: 1742–1751.

Deckelbaum RJ, Palm C, Mutuo P, DeClerck F (2006) Econutrition: Implementation models from the Millennium Villages Project in Africa. Food Nutr Bull 27 (4): 335-342.

DeClerck F, Ingram JC, Rumbaitis del Rio CM (2006) The role of ecological theory and practice in poverty alleviation and environmental conservation. Front Ecol Environ 4: 533–540.

Díaz, S, Cabido M (2001) Vive la différence: plant functional diversity matters to ecosystem processes. Trends in Ecology & Evolution 16:646-655.

Drescher LS, Thiele S, Mensink GBM (2007) A new index to measure healthy food diversity better reflects a healthy diet than traditional measures. J Nutr 137: 647-651.

Flynn DFB, Gogol-Prokurat M, Nogeire T , Molinari N ,Trautman Richers B, et al. (2009) Loss of functional diversity under land use intensification across multiple taxa. Ecology Letters 12: 22-33.

Flynn DFB, Mirotchnick N, Jain M, Palmer M, Naeem S (2011) Functional and phylogenetic diversity as predictors of biodiversity-ecosystem function relationships. Ecology. In press.

Food and Agriculture Organization of the United Nations (2010). The State of Food Insecurity in the World 2010. FAO, Rome.

Food and Agriculture Organization and Food and Nutrition Technical Assistance Project (2008) Guidelines for Measuring Household and Individual Dietary Diversity. FAO, Rome.

Food and Agriculture Organization of the United Nations and World Health Organization (1988). Human vitamin and mineral requirements.

Food and agriculture organization of the United Nations (2010) Global forum on food security and nutrition. Knowledge sharing for improved food security and better nutrition. FAO, Rome.

Frison E, Smith IF, Johns T, Cherfas J, Eyzaguirre PB (2006) Agricultural biodiversity, nutrition, and health: Making a difference to hunger and nutrition in the developing world. Food Nutr Bull 25: 143-155.

Graham RD, Welch RM, Saunders DA, Ortiz-Monasterio I, Bouis HE, et al. (2007) Nutritious subsistence food systems. Advances Agronomy 92: 1-72.

Graham RD (2008) Micronutrient Deficiencies in Crops and Their Global Significance. In Alloway BJ (eds) Micronutrient Deficiencies in Global Crop Production. Springer, pp. 41-62.

Hatloy A, Torheim L, Oshaug A (1998) Food variety - a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. Eur J Clin Nutr 52: 891–898.

International Assessment of Agricultural Knowledge, Science and Technology for Development (2009) Island Press, Washington D.C.

International Food Policy Research Institute (1998) Commercial Vegetable and Polyculture Fish Production in Bangladesh: their Impacts on Income, Household Resource Allocation and Nutrition, Volumes 1 and 2. IFPRI, Washington, DC.

Kant A, Schatzkin A, Harrris T, Ziegler R, Black G (1993) Dietary diversity and subsequent mortality in the First National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. Am J Clin Nutr 57: 434–440.

Kennedy G, Berardo A, Papavero C, Horjus P, Ballard T, et al. (2010) Proxy measures of household food consumption for food security assessment and surveillance: comparison of the household dietary diversity and food consumption scores. Public Health Nutr 13: 2010-2018.

Kennedy G, Islam O, Eyzaguirre P, Kennedy S (2005) Field testing of plant genetic diversity indicators for nutrition surveys: rice-based diet of rural Bangladesh as a model. J Food Comp Analysis 18: 255–268.

Kennedy G, Burlingame B (2003) Analysis of food composition data on rice from a plant genetic resources perspective. Food Chemistry 80: 589-596.

Laliberté E, Legendre P (2010) A distance-based framework for measuring functional diversity from multiple traits. Ecology 91:299-305.

Lambrecht I (2009) Linking agro-diversity and nutrition: A case study in two Millennium Villages. Master thesis, Katholieke Universiteit Leuven.

Latham M (2010) The great vitamin A fiasco. World Nutrition 1: 12-45.

Levi F, Pasche C, La Vecchia C, Lucchini F, Franceschi S, et al. (1998) Food groups and risk of oral and pharyngeal cancer. Int J Cancer 77: 705–709.

Maundu PM, Ngugi GW, Kabuye CHS (1999) Traditional food plants of Kenya. IPGRI, Rome.

Maundu PM, Tengnèas B, Birnie A, Muema N (2005) Useful Trees and Shrubs for Kenya. World Agroforestry Centre, Nairobi.

McLaren DS (1966) A fresh look at protein calorie malnutrition. Lancet 2: 485–488.

McLaren DS (1974) The great protein fiasco. Lancet 2: 93–96.

McLean E, Cogswella M, Eglia I, Wojdylaa D, de Benoista B

(2009) Worldwide prevalence of anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993–2005. Public Health Nutr 12:444-454.

Millennium Villages Project (2010) Harvests of Development in Rural Africa: The Millennium Villages After Three Years. MVP, New York.

Mouchet MA, Villeger S, Mason NWH, Mouillot D (2010) Functional diversity measures: an overview of their redundancy and their ability to discriminate community assembly rules. Functional Ecology, 24, 867-876.

Moursi MM, Arimond M, Dewey KG, Trèche S, Ruel MT, et al. (2008) Dietary diversity is a good predictor of the micronutrient density of the diet of 6- to 23-month-old children in Madagascar. J Nutr 138: 2448-2453.

National Academy of Sciences (2009) Dietary Reference Intakes: Recommended Intakes for Individuals. Washington, D.C.

National Research Council (1996) Lost crops of Africa Volume I: Grains. National academy press, Washington D.C.
National Research Council (2006) Lost crops of Africa Volume II: Vegetables. National academy press, Washington D.C.

National Research Council (2008) Lost crops of Africa Volume III: Fruits. National academy press, Washington D.C.

Negin J, Remans R, Karuti S, Fanzo JC (2009) Integrating a broader notion of food security and gender empowerment into the African Green Revolution. Food Sec 1: 351–360.

Niles D, Roff RJ (2008) Shifting agrifood systems: the contemporary geography of food and agriculture; an introduction. GeoJournal 73: 1-10.

Nziguheba G, Palm CA, Berhe T, Denning G, Dicko A, et al. (2010) The African Green Revolution: Results from the Millennium Villages Project. Advances Agronomy 109: 75- 115.

Petchey OL, Gaston KJ (2002) Functional diversity (FD), species richness, and community composition. Ecology Letters 5: 402-411.

Petchey OL, O'Gorman EJ, Flynn DFB (2009) A functional guide to functional diversity measures. In Biodiversity, Ecosystem Functioning, & Human Wellbeing (eds Naeem S, Bunker DE, Hector A, Loreau M, Perrings C). Oxford University Press, Oxford pp. 49-59.

Petchey OL, Evans, KL, Fishburn IS, Gaston KJ (2007) Low functional diversity and no redundancy in British avian assemblages. J Animal Ecology, 76: 977-985

Peters CJ, Nelson L. Bills NL, Wilkins JL, Fick GW (2008) Foodshed analysis and its relevance. Ren Agr Food Syst doi:10.1017/S1742170508002433

Remans R, Fanzo J, Palm C, DeClerck F (2011) Ecology and human nutrition. In DeClerck (eds) Ecology and poverty. Springer. In press.

Rose D, Chotard S, Oliveira L, Mock N, Libombo M (2008) A comparative evaluation of dietary indicators used in food consumption assessments of at-risk populations. Food Nut Bull 29: 113-122

Rose D, Burgos G, Bonierbale M, Thiele G (2009) Understanding the role of potatoes in the Peruvian diet: An approach that combines food composition with household expenditure data. J Food Compos Anal 22: 525-532.

Rumbaitis del Rio CM, Ingram JC, Declerck F (2005) Leveraging ecological knowledge to end global poverty. Front Ecol Environ 3: 463-463.

Sachs JD, Remans R, Smukler SM, Winowiecki L, Andelman S, et al. (2010) Monitoring World's agriculture. Nature 466: 558-560.

Sanchez P, Palm C, Sachs JD, Denning G, Flor, R, et al. (2007) The African Millennium Villages. Proc Natl Acad Sci U S A 104: 16775–16780.

Shimbo S, Kimura K, Imai Y, Yasumoto K, Yamamoto K, et al. (1994) Number of food items as an indicator of nutrient intake. Ecol Food Nutr 32:197–206.
Slattery M, Berry T, Potter J, Caan B (1997) Diet diversity, diet composition and risk of colon cancer. Cancer Causes Control 8: 872–882.

Smith IF, Eyzaguirre P (2007) African Leafy Vegetables: their role in the World Health Organization's Global Fruit and Vegetables. Afr J Food Agr Nutr Vol 7, No. 3.
http://www.ajfand.net/Vol7No3.html

Steyn NP, Nela JH, Nantela G, Kennedy G, Labadariosa D (2006) Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? Public Health Nutrition 9: 644-650.

United Nations Children's Fund (2009) Tracking progress on child and maternal nutrition. UNICEF, New York.

UN Millennium Project (2005) Investing in Development. A Practical Plan to Achieve the Millennium Development Goals. Earthscan, London.

Waijers PMCM, Feskens EJM, Ocke MC (2007) A critical review of predefined diet quality scores. Br J Nutr 97: 219–231.

Welch RD, Graham RD (1999) A new paradigm for world agriculture: meeting human needs. Productive, sustainable, nutritious. Field Crops Research 60: 1-10

World Bank (2007) From Agriculture to Nutrition. Pathways, Synergies, and Outcomes. World Bank, Washington, D.C.

World Health Organization (2007). Joint statement by the World Health organization, the World Food Programme and the united nations children's Fund: Preventing and controlling micronutrient deficiencies in populations affected by an emergency. WHO, Geneva.

World Health Organization (2003). Obesity and Overweight. WHO, Geneva.

NUTRIENT DIVERSITY WITHIN RICE CULTIVARS (ORYZA SATIVA L) FROM INDIA

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Abstract
Rice research in India has focused mainly on increasing yield and little is known of the nutrient composition of many of the country's rice varieties. This study investigates the variations in the nutrient content of 269 high-yielding Indian rice cultivars. Protein content ranged from 6.92 to 12.98 g/100 g with a mean of 9.43 ± 1.22 g/100 g. The majority of the samples (51%) had protein content between 9 and 12 g/100 g. Mean crude fat content was 2.38 ± 0.46 g/100 g and as many as 30 cultivars had more than 3 g/100 g. Moderate levels of total dietary fibre (3.99–4.71 g/100 g) were observed in the brown rice samples. Mean ash content was 1.39 ± 0.18 g/100 g and 36 percent of the samples had ash content between 1.5 and 2.0 g/100 g indicating mineral abundance in many rice varieties. High concentrations of macro-elements such as phosphorus (330 ± 81 mg/100 g), potassium (253 ± 27.81 mg/100 g) magnesium (129 ± 16 mg/100 g) and calcium (13.12 ± 2.66 mg/100 g) were observed. Grain iron content ranged from 0.57 to 4.04 mg/100 g with an average of 1.36 ± 0.59 mg/100 g. The coefficient of variation observed for grain iron content was as high as 43 percent. Grain zinc content ranged from 1.46 to 3.87 mg/100 g with a coefficient of variation of 19 percent. Essential amino acids made up 39 percent of the total amino acids. The amino acid score ranged from 59 to 73 (mean 65 ± 3.42) and Lysine was the limiting amino acid. Palmitic (range 20–26%), oleic (30–37%) and linoleic acids (33–42%) accounted for more than 92 percent of the total fatty acids in rice. The study has revealed diverse rice varieties with wide-ranging nutrients that can be utilized in breeding programmes to effectively increase protein and micronutrient content in rice.

1. Introduction
Rice is rich in genetic diversity with thousands of varieties cultivated in more than 100 countries around the world. Nearly all cultivated rice is Oryza sativa L. with a small amount of O. glaberrima grown in Africa. It is estimated that there are 120 000 different cultivars ranging from traditional rice varieties to the commercially bred elite cultivars (Londo et al., 2006). In its natural state, rice comes in many different colours prized for their nutrient and health properties. Rice is tied to cultures and livelihoods symbolizing life and prosperity for billions of people playing a fundamental role in the world food security and socio-economic development. To emphasize the importance of rice, the UN General Assembly declared 2004 the International Year of Rice under the slogan "Rice is Life" (FAO, 2004).

India is the largest rice-growing country accounting for one-third of the world acreage under rice cultivation. Rice is grown in almost all the Indian states covering more than 30 percent of the total cultivated area in the country. India's food production is projected to touch 235 million tonnes during 2010–11, of which rice will account for 94.5 million tonnes (Directorate of Economics and Statistics, 2010). Each year an estimated 408 661 million tonnes of rice is consumed across the globe accounting for 20 percent of the world's total calorie intake. The biggest public health challenge both globally and in rice-consuming countries comes from micronutrient deficiencies of iron, zinc, vitamin A and iodine affecting more than 3 billion people worldwide (WHO, 2002). The proportion of the global population suffering from micronutrient deficiencies has increased over the last four decades largely due to the increase in acreage under rice and wheat cultivation at the expense of pulse crops (a much richer source of micronutrients) and to changing dietary habits (Graham et al., 2007). India has the highest incidence of undernutrition in the world, and of the micronutrient deficiencies, iron deficiency anaemia is the most serious public health problem in the country (NNMB, 2006).

In the past, generic food composition data were considered sufficient for most purposes but today the usefulness of cultivar-specific composition data is becoming increasingly acknowledged for understanding diet-related morbidity and mortality. Significant cultivar-specific differences have been observed in the nutritional content of rice (Kennedy and Burlingame, 2003). Many factors, such as climate, geography and geochemistry, agricultural practices, post-harvest conditions and handling, as well as genetic composition of the cultivar are known to affect the nutrient composition of rice. Among these factors cultivar-specific differences have received the least attention.

Rice research in India has traditionally focused on ways of increasing yield to match the country's burgeoning population and trade. The importance of enhancing nutritional quality to improve human health through rice breeding is only now coming in focus. In 2002, the International Rice Commission recommended that the existing biodiversity of rice varieties and their nutritional composition needed to be explored and that nutrient content must be among the main criteria used for selection of rice cultivars for use in areas of food insecurity. Rice is an important source of nutrients and breeding rice crops with particularly enhanced nutrient concentration requires knowledge of the variation in the trait among the available germplasm. Therefore this study was initiated in order to document the nutrient composition of 269 high-yielding rice cultivars cultivated in India. Nutrient analysis was carried out using brown rice, the raw material for white rice.

2. Methodology

2.1 Sample processing

All varieties (indica subspecies) of rice were supplied by the Directorate of Rice Research (ICAR), Rajendranagar, Hyderabad in the form of brown rice. Samples were powdered using cyclone mill (UDY Corporation, USA) and stored in clean polyethylene bottles from where aliquots were taken for analysis.

2.2 Proximate composition

Moisture, ash and dietary fibre content were assayed using the Association of Official Analytical Chemists (AOAC, 2006) methods 934.01, 942.05 and 985.29, respectively. Protein content (N X 5.95) was determined by the AOAC Kjeldahl method (984.13). Total fat was determined by the AOAC method after acid digestion (996.01). Carbohydrate content was determined by calculating the difference (100 – moisture+fat+protein+ash+total dietary fibre).

2.3 Mineral analysis

Approximately 0.5 g of sample was accurately weighed into a Teflon PFA digestion vessel to which high purity acid mixture (3.0 mL HNO3 and 1.0 mL H2O2) was added. Each sample was taken in duplicate, sealed and digested in a microwave digestion system (CEM, Corp. MARSXpress). After completion of the digestion, vessels were cooled, carefully removed and transferred to a 25 ml volumetric flask. Analysis of calcium, copper, iron, magnesium, manganese, potassium and zinc was carried out after appropriate dilutions in an Atomic Absorption Spectrometer (iCE 3300 Thermo Scientific). Phosphorus was estimated by the Fiske and Subbarow method as described in AOAC method (931.01).

2.4 Quality control

For mineral estimation a blank and a Certified Reference Material (NIST 1568a or 1547) were included in each digestion batch for quality assurance. A comparison of the mean content values for each of the analyte in this study and that given in the CRM certificate is presented in Table 1. The precision data shows good agreement reflecting good data quality.

Table 1. Analysis of Certified Reference Material

Minerals	CRM No.	Sample	Measured Value (mg/kg)	Certified Value (mg/kg)
Fe	NIST-1568a	Rice Flour	7.57 ± 0.16	7.4 ± 0.9
Zn	NIST-1568a	Rice Flour	19.22 ± 0.35	19.4 ± 0.5
Cu	NIST-1568a	Rice Flour	2.4 ± 0.155	2.4 ± 0.3
Mn	NIST-1568a	Rice Flour	18.52 ± 0.376	20.0 ± 1.6
Ca	NIST-1568a	Rice Flour	118 ± 2.3	118 ± 6
Mg	NIST-1568a	Rice Flour	560 ± 3	560 ± 20
K	NIST-1568a	Rice Flour	1280 ± 3.2	1280 ± 8
P	NIST-1547	Peach Leaves	1360 ± 16	1370 ± 70

2.5 Amino acid composition

Amino acid analysis was carried out by hydrolysing the samples in sealed ampoules in vacuo with 6 N HCl and incubated at 110ºC for 22 hours (Darragh, 2005). Excess acid was removed in a flash evaporator under reduced pressure at a temperature of less than 40ºC. The sample was then dissolved in a citrate buffer (pH 2.2) and loaded into an automatic amino acid analyser (Biochrom-30, Cambridge, UK). Methionine and cysteine was determined separately after performic acid oxidation (Moore, 1963). Tryptophan was quantified after barytic hydrolysis of the samples according to the method described by Landry and Delhaye (1992). Each amino acid was identified and quantified using authentic standards (National Institute of Standards and Technology, SRM 2389). The amino acid score was calculated using the FAO/WHO/UNU suggested pattern of amino acid requirement for pre-school children (2–5 years) (FAO/WHO/UNU, 1985).

2.6 Fatty acid composition

The fatty acid composition was determined after direct methylation of the samples according to the method of O' Fallon et al. (2007). The fatty acid methyl esters were analysed in a Shimadzu 2010 GC equipped with Flame Ionization Detector (FID) and SP2560 column (100 m x 0.25 mm x 0.2 mm). Injection was achieved by splitless mode and the injection port and detector were maintained at 250°C. Nitrogen was used as carrier gas and the temperature programme was from 140°C to 230°C with a ramp rate of 4°C/min. Individual peaks were identified by retention time using SupelcoTM37 component FAME MIX. Fatty acid composition was expressed as a percentage of total fatty acids.

2.7 Statistical calculations

Data analysis was carried out using SPSS (Version 18: Chicago, IL). Descriptive statistics, namely mean, range and standard deviation, were calculated. Pearson correlation coefficients were carried out among the different nutrients of interest. P values were two-tailed and two significant levels (P←0.05 and 0.01) were used.

3. Results and discussions

3.1 Proximate composition

The macronutrient composition of all the rice varieties is listed in table 2.

Table 2. Proximate composition and dietary fiber content of 269 high yielding Indian rice varieties

Parameter	N	Mean ± SD	Range
Moisture (g/100g)	269	9.69 ± 1.37	6.15 – 12.66
Protein (g/100g)	269	9.47 ± 1.22	6.92 – 12.98
Fat (g/100g)	269	2.36 ± 0.46	1.23 – 3.77
Ash (g/100g)	269	1.39 ± 0.18	0.90 – 1.99
Insoluble dietary fibre (g/100g)	205	3.62 ± 3.64	3. 13.90
Soluble dietary fibre (g/100g)	105	0.79 ± 0.06	0.66 – 0.92
Total dietary fibre (g/100g)	105	4.41 ± 0.17	3.99 – 4.71
Carbohydrate (g/100g)	105	71.79 ± 1.37	68.04 – 75.77
Energy (kcal)	105	347 ± 3.64	340 - 356

All samples had moisture content varying between 6.15 and 11.91 g/100 g within the limit of 12 g/100 g normally recommended for safe storage of processed rice. Brown rice protein content in 269 cultivars studied ranged from 6.92 to 12.98 g/100 g. The width between the highest and the lowest protein content was 6 g/100 g. The average rice protein content of 9.43 g/100 g found in the present study was much higher than the reported value of 6.88 g/100 g in the Indian Food Composition Tables (Gopalan et al., 1989) indicating a general increase of protein content in Indian rice varieties. Factors such as environmental condition, soil fertility, fertilizer use and post-harvest processing can influence the protein content of rice; however, the present study examines only the varietal difference and not the other factors that can influence protein content in rice.

Protein content in rice due to varietal differences has been reported to be in the range of 4.5 to 15.9 g/100 g (Juliano and Villareal, 1993). Compared to the present study, Chandel et al. (2010) has reported lower protein content ranging from 6.95 to 10.75 g/100 g with an average of 8.07 g/100 g while Basak et al. (2002) reported a much lower protein content of 6.6–7.3 g/100 g in Indian rice genotypes. Chinese and North American wild rice samples had a relatively higher protein content of 12–15 g/100 g (Zhai et al., 2001). Frequency distribution showed that 45.2 percent of the samples had protein content below 9 g/100 g while only 3 percent of the samples were above 12 g/100 g. The highest protein content of 12.98 g/100 g was observed in Phoudum, a traditional high-yielding variety. The majority of the samples (51%) had a protein content of between 9 and 12 g/100 g.

Brown rice crude fat content in 269 Indian rice cultivars ranged from 1.23 to 3.77 g/100 g with a mean of 2.38 ± 0.46 g/100 g which is comparable to that reported by other investigators (Juliano, 1985; Scherz et al., 2000). Similar fat content ranging from 1.81 to 2.24 g/100 g and from 2.1 to 3.2 g/100 g has been reported in Italian rice varieties (Brandolini et al., 2006). The highest fat content of 3.77 g/100 g found in Kavya variety is substantially high even though it is within the range of 1 – 4 g/100 g reported for brown rice (Juliano, 1985). Frequency distribution of brown rice fat content showed that the 73 percent of the samples had fat content between 2 and 3 g/100 g while as many as 30 cultivars had more than 3 g/100 g. Though rice is not a rich source of fat, the study revealed that considerable variations exist within rice cultivars with some cultivars having substantially higher content that can be utilized to marginally increase fat intake.

The total dietary fibre content analysed in 105 rice varieties ranged from 3.99 to 4.71 g/100 g, with MLT-ME6 having the highest content. The average insoluble fibre and soluble fibre content was 3.62 ± 0.16 g/100 g and 0.79 ± 0.06 g/100 g, respectively. In all varieties, the content of insoluble dietary fibre was significantly greater (p←0.001) than that of soluble dietary fibre. Compared to the present study, Cheng (1983) has reported a much lower total dietary fibre content of 1.36 – 2.83 g/100 g in brown rice. Rice appears to be a moderate source of dietary fibre; however, milling or polishing to produce white rice drastically reduces the dietary fibre content in rice. In Asian countries where higher intake of white rice has been associated with increased risk of metabolic diseases and type 2 diabetes, substitution with brown rice has shown to lower the risk of type 2 diabetes, CVD and mortality (Katcher et al., 2008; Villegas et al., 2007). Therefore using brown rice to overcome current physiological effects in human health due to its high fibre and other bioactive compounds appears to be an advantage.

Brown rice ash content in 269 rice cultivars ranged from 0.9 g/100 g in Pantdh to 1.99 g/100 g in IR36 variety. Mean brown rice ash content was 1.38 g/100 g, comparable to brown rice from Brazil (1.21 g/100 g) and wild rice varieties from China (Heinemann et al., 2005; Zhai et al., 2001). Frequency distribution showed that 64 percent of the samples had ash content between 0.9 and 1.5 g/100 g, while 36 percent had ash content between 1.5 and 2.0 g/100 g reflecting mineral abundance in many rice varieties.

3.2 Mineral Content

The concentration of elements in 269 brown rice genotypes is summarized in table 3.

Table 3. Mineral content of high yielding Indian rice varieties (mg/100g)

Min.	N	PRESENT STUDY		Juliano and Bechtel (1985)	Marr et al (1995)	Scherz et al (2000)
		Mean ± SD	Range			
Fe	236	1.23 ± 0.53	0.52 – 3.75	0.2 – 5.2	0.5 – 5.7	2 – 3.6
Zn	236	2.38 ± 0.45	1.01 – 3.46	0.6 – 2.8	1.3 – 2.1	0.8 – 2
Cu	236	0.31 ± 0.10	0.13 – 0.78	0.1 – 0.6	0.14 – 1.3	0.24 – 0.30
Mn	236	1.41 ± 0.31	0.75 – 2.46	0.2 – 3.6	2.5 – 6	3.74
Ca	236	12.27 ± 2.59	8 – 19	10 – 50	3 – 11	11 – 39
Mg	236	116 ± 14.04	69 – 150	20 – 150	100 – 130	110 – 166
P	236	297 ± 71.18	113 – 4987	170 – 430	240 – 310	250 – 383
K	104	253 ± 27.81	162 - 347	60 - 280	210 – 300	150 – 260

The sum of nutritionally important minerals assayed in this study represents 36 percent of the total ash content. In general, high concentrations of macro-elements such as phosphorus (330 ± 81 mg/100 g), potassium (253 ± 27.81 mg/100 g), magnesium (129 ± 16 mg/100 g) and calcium (13.12 ± 2.66 mg/100 g) was observed in the Indian rice cultivars. The levels of macro-elements found in the present study was comparable with the values obtained by Zeng et al. (2009) in 28 indica brown rice from China. Phosphorus content was highest in T. Basmati (465 mg/100 g) and lowest in Aathira (195 mg/100 g). More than 80 percent of the total phosphorus content in rice occurs as phytate that functions in chelating and storing phosphorus in the seed (Oatway et al., 2001). Magnesium content ranged from 86 mg/100 g in MLT-E-2 to 149 mg/100 g in Chageli variety. The variation in calcium content was from 6.8 mg/100 g in Aanashwara to 17.11 mg/100 g in Pantdhan-12. Mean ± SD content of manganese and copper was 1.56 ± 0.35 and 0.34 ± 0.11 mg/100 g respectively. Copper content was low ranging from 0.14 to 0.84 mg/100 g. Manganese content was lowest in Aathira (0.77 mg/100 g) and highest in MLT-M-11 (2.13 mg/100 g). Element transfer from soil to brown rice has been studied and inter-regional differences in the concentration of various elements were not found to be substantial in many cases (Jung et al., 2005). The order of the concentrations of elements in brown rice in this study was phosphorus → magnesium → calcium → zinc → manganese → iron → copper. Similar trends have been observed by other investigators conducting studies on different rice varieties (Ogiyama et al., 2008).

Grain iron content ranged from 0.57 mg/100 g in Aathira to 4.04 mg/100 g in MLTE-5 with an average of 1.36 ± 0.59 mg/100 g on dry weight basis. Frequency distribution of iron content showed that 46 percent of the samples had less than 1 mg/100 g, 48 percent had 1 – 2 mg/100 g and 6 percent had more than 2 mg/100 g. Rice grain iron content has been reported to be in the range of 0.2 – 5.2 mg/100 g by Juliano and Bechtel (1985). A much lower iron content has been reported in wild rice accession (1.25 – 2.27 mg/100 g), advance breeding lines (0.81 – 1.28 mg/100 g) and landraces (0.48 – 1.62 mg/100 g) in 46 Indian rice genotypes by Chandel et al. (2010). Compared to the present study higher iron content in the range of 0.70 – 6.35 mg/100 g with an average of 2.28 mg/100 g on dry matter basis was reported for 95 Chinese varieties (Wang et al., 1997). Similarly high iron content in the range of 0.5 – 6.7 mg/100 g has been reported in 90 Australian rice varieties (Marr et al., 1995) while Korean rice varieties showed low content of 0.16 – 1.4 mg/100 g (Kim et al., 2004). Interestingly high iron content of 5.06 ± 1.05 mg/100 g has been reported in improved indica cultivar from China (Zeng et al., 2009). On the other hand low iron content of 1.2 mg/100 g was reported in Vietnamese rice (Phuong et al., 1999). The coefficient of variation observed for grain iron content in the present study was as high as 43 percent which indicates ample room for improving rice iron content.

Grain zinc content ranged from 1.46 mg/100 g in Lalat to 3.87 mg/100 g in MLT-M-14 with a coefficient of variation of 19 percent. Frequency distribution showed that 73 percent of the samples had zinc content in the range of 1 – 2 mg/100 g and 14 percent had more than 2 mg/100 g. Varying grain zinc content in 46 rice genotypes from India was found to be 2.96 – 4.17 mg/100 g in wild rice accession, 1.67 – 3.01 mg/100 g in advance breeding lines and 2.07 – 2.96 mg/100 g in landraces (Chandel et al., 2010). Zeng et al. (2009) found zinc content of 2.57 ± 0.67 mg/100 g in improved Indian cultivars which is comparable to 2.64 ± 0.50 mg/100 g found in the present study though higher zinc content of 3.34 mg/100 g has also been reported in 57 Chinese rice varieties (Wang et al., 1997). Increased nitrogen fertilizer application did not produce significant increases in grain iron and zinc content in rice (Chandel et al., 2010). The width between the lowest and highest zinc content in the present study was 2.41 mg/100 g while that of iron was much higher at 3.47 mg/100 g. Rice is not a rich source of iron and zinc but it remains the major source of intake for these micronutrients in the rice-eating population.

3.3 Correlations among the contents of ash and eight mineral elements in brown rice

Results of the Pearson's correlation performed among eight mineral element content and ash in brown rice is given in table 4.

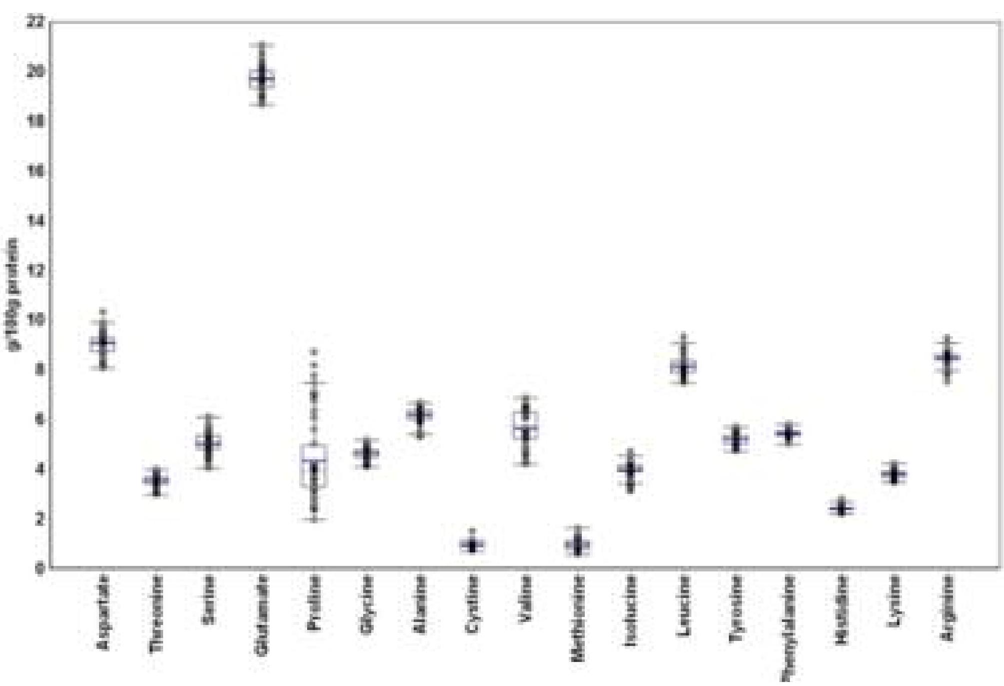
Table 4. Correlation among eight mineral contents in 269 high yielding Indian rice cultivars

El.	Ash	Fe	Zn	Cu	Mn	Ca	Mg	P
Fe	0.192**							
Zn	0.235**	0.187*						
Cu	0.71	0.432**	0.209**					
Mn	-0.097	0.058	-0.120	0.167*				
Ca	-0.018	0.159*	-0.148*	0.057	0.135*			
Mg	0.286**	0.166*	0.410**	0.191**	-0.008	-0.226**		
P	0.152*	0.205**	-0.159*	0.010	0.287**	-0.103	0.156*	
K	0.212*	0.082	0.108	0.118	0.103	0.292**	0.215*	-0.100

* Significant at 0.05 probability level
** Significant at 0.01 probability level

Ash correlated positively with Fe or Zn or Mg or P or K but showed no correlation with Cu or Mn or Ca indicating that all the mineral content in rice is not positively correlated with its ash content. Among the minerals, close positive correlation was observed between the contents of Zn and Fe, Cu and Fe or Zn, Mn and Cu, Ca and Fe or Mn, Mg and Fe or Zn or Cu, P and Fe or Mn or Mg, K and Ca or Mg, while negative correlation was observed between the content of Ca and Zn, Mg and Ca, P and Zn. Jiang et al. (2007) also observed positive correlation between Fe and Zn suggesting that high iron content is accompanied by high zinc content in rice. There were differences in the correlations among other elements between the Chinese rice genotypes and the present study which may be due to the fact that Jiang et al. (2007) used polished rice whereas brown rice was used in the present study. Significant positive correlation was observed between Mg and all other elements studied except Mn. This may be explained by the fact that Mg regulated the uptake of all other essential elements and thus the Mg content of rice grain assumes importance (Tucker, 1999). The mineral contents in the Indian rice varieties are very diverse which can be explained by the genetic characteristics of varieties and other agri-

Figure 1. Box plot showing the distribution of various amino acids in 42 high Yielding Indian rice varieties



cultural practices that can influence its contents.

3.4 Amino acid content and Amino acid score

Box plot showing distribution of various amino acids in 42 high yielding rice cultivars is shown in Figure 1. The total essential amino acids made up 39% of the total amino acids. Lysine content ranged from 3.42g/100g in AP 41 Kanchana to 4.2g/100g in AP 71 Pratap with a mean of 3.76 ± 0.20 g/100g protein. Shekar and Reddy (1982) has also reported wide variation in lysine content (2.82 to 4.86g/100g protein) in scented rice varieties. In contrast low lysine content (2.8g/100g protein) was observed in Mexican and Malaysian rice varieties (Roohinejad et al 2009; Sotelo et al, 1994). In the present study besides AP71 Pratap another two varieties AP 85 Sarala and AP106 also had lysine content above 4 g/100g protein. Wide genetic variability for lysine content in Indian rice varieties has been reported (Banerjee et al, 2011). The mean ± SD of threonine content, the second limiting amino acid in rice was 3.45 ± 0.21 g/100g protein. The lowest threonine content of 3.03 g/100g protein was observed in IR 64 while the highest content of 3.86 g/100g protein was found in AP 85 Sarala. After lysine and threonine, isoleucine is the only amino acid that can sometimes be limiting in rice protein. Isoleucine content ranged from 3.02 – 4.59 g/100g protein with mean content of 3.91 ± 0.39 g/100g protein. The savoury amino acids glutamate and aspartate was the major amino acids constituting 19.36 ± 0.39 and 8.91 ± 0.38 g/100g protein respectively. The sweet amino acids glycine and alanine was as high as 4.51±0.20 and 6.01±0.29 g/100g protein respectively. The range of the different essential amino acids expressed in g/100g protein was 1.32 – 1.54 for tryptophan, 1.51 – 3.04 for cysteine, 4.05 – 6.92 for valine, 1.11 – 2.40 for methionine, 7.23 – 8.73 for leucine, 5.12 – 5.75 for phenylalanine, 2.23 – 2.73 for histidine and 7.53 – 8.62 for arginine. There was reasonable level of variation for all the amino acids indicating that genetic gain by means of selection is likely.

Compared to the WHO/FAO/UNU (1985) amino acid requirement for 2-5 years old child the amino acid score ranged from 59 to 73 with a mean of 65 ± 3.42. Compared to lysine content in rice varieties from other studies (Hegsted and Julaino 1974; Sotelo et al 1994; Tobekia et al, 1981), generally higher lysine content was observed in the present study. Despite observing

Table 5. Correlation among amino acids and protein content in 42 high yielding Indian rice cultivars

	Try	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Cys	Val	Met	Ile	Ley	Tyr	Phe	His	Lys	Arg
Asp	0.368*																	
Thr	0.175	0.800**																
Ser	0.215	0.756**	0.845**															
Glu	0.126	0.137	0.146	0.390*														
Pro	0.222	-0.076	-0.054	0.115	0.264													
Gly	0.199	0.742**	0.816**	0.581**	0.009	-0.214												
Ala	0.149	0.711**	0.832**	0.681**	0.227	-0.224	0.794**											
Cys	0.466**	0.513**	0.412**	0.455**	0.147	0.042	0.332*	0.412**										
Va	-0.033	-0.549**	-0.490**	-0.521**	0.060	0.211	-0.357*	-0.391*	-0.143									
Met	0.329*	0.558**	0.524**	0.446**	0.141	0.200	0.512**	0.450**	0.330*	-0.264								
Ile	0.145	-0.274	-0.249	-0.488**	-0.155	-0.012	-0.040	-0.090	0.060	0.735**	-0.042							
Ley	0.012	0-.503**	-0.487**	-0.375*	0.280	0.261	-0.474**	-0.381*	0.002	0.905**	-0.309*	.564**						
Tyr	0.434**	0.313*	0.169	0.228	0.373*	0.120	0.139	0.264	0.313*	-0.208	0.286	0.138	-0.073					
Phe	0.303	0.022	-0.071	-0.067	0.347*	-0.025	0.150	0.102	-0.011	0.453**	0.049	0.420**	0.416**	0.364*				
His	0.190	0.430**	0.486**	0.193	-0.123	-0.200	0.570**	0.403**	0.277	0.094	0.336*	0.435**	-0.012	0.032	.0208			
Lys	0.044	0.343*	0.333*	0.081	-0.354*	-0.075	0.413**	0.199	0.257	0.234	0.278	0.419**	0.041	-0.134	0.127	0.603**		
Arg	0.242	0.204	0.241	0.200	-0.025	0.159	0.357*	0.047	0.101	0.108	0.353*	0.188	-0.010	0.248	0.186	0.251	0.405**	
Protein	-0.281	-0.789**	-0.676**	0-.475**	0.173	0.225	-0.658**	-0.620**	-0.310	0.843**	-0.557**	0.286	0.881**	-0.452**	0.206	-.0332*	-0.169	-0.174

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

increased lysine content in some cultivars, this amino acid still remains the first limiting amino acid in all varieties. Milling does not induce any dramatic changes in the amino acid composition of rice and thus the amino acid score is unlikely to change significantly due to polishing (Sotelo et al, 1994; Tobekia et al, 1981).
Table 5 shows the correlation among the different amino acids including protein content. Significant negative correlations was observed between protein content and Asp or Thr or Ser or Gly or Ala or Met or Trp or His indicating that increase in protein content will result at the expense of these amino acids. A positive correlation was observed between Lys and Asp or Thr or Gly or Iso or His while a negative correlation was seen between Lys and Glu. The second limiting amino acid threonine showed significant correlation with Ser or Gly or Ala or Cys or Met or His or Lys. Negative correlation was also observed between Thr and Val or Leu. Significant correlations was observed between many combinations of amino acid in the Indian rice cultivars. The results suggest that many Indian rice varieties possess better amino acid profiles and exhibit superior nutritional qualities which could be utilized in breeding varieties with improved amino acid composition.

3.5 Fatty acids composition

Box plot showing the distribution of various fatty acids in 85 Indian rice cultivars is presented in Figure 2. The major fatty acids were palmitic (range 20 – 26%), oleic (range 30 – 37%) and linoleic acids (33 – 42%) which accounted for more than 92% of the total fatty acids. Studies on non-glutinous rice cultivars from Japan also showed similar content of the major fatty acids palmitic, oleic and linoleic acids (Kitta et al, 2005). The Mean ± SD content of myristic , stearic and α-linolenic acids was 0.32 ± 0.06, 2.63 ± 0.50 and 1.52 ± 0.23 respectively. α-linolenic content ranged from low of 0.93 to as high as 2.19%. Capric acid was detected at very low levels ranging between 0.02 – 0.32 % in the present study. There is no report on the presence of Capric acid in rice and this is the first report of the kind. A sample chromatogram of one rice fatty acid profile showing distinct peak of capric acid is depicted in Figure 3. Detection of capric acid was achieved by

Figure 2. Box plot showing the distribution of various fatty acids in 85 high yielding Indian rice cultivars

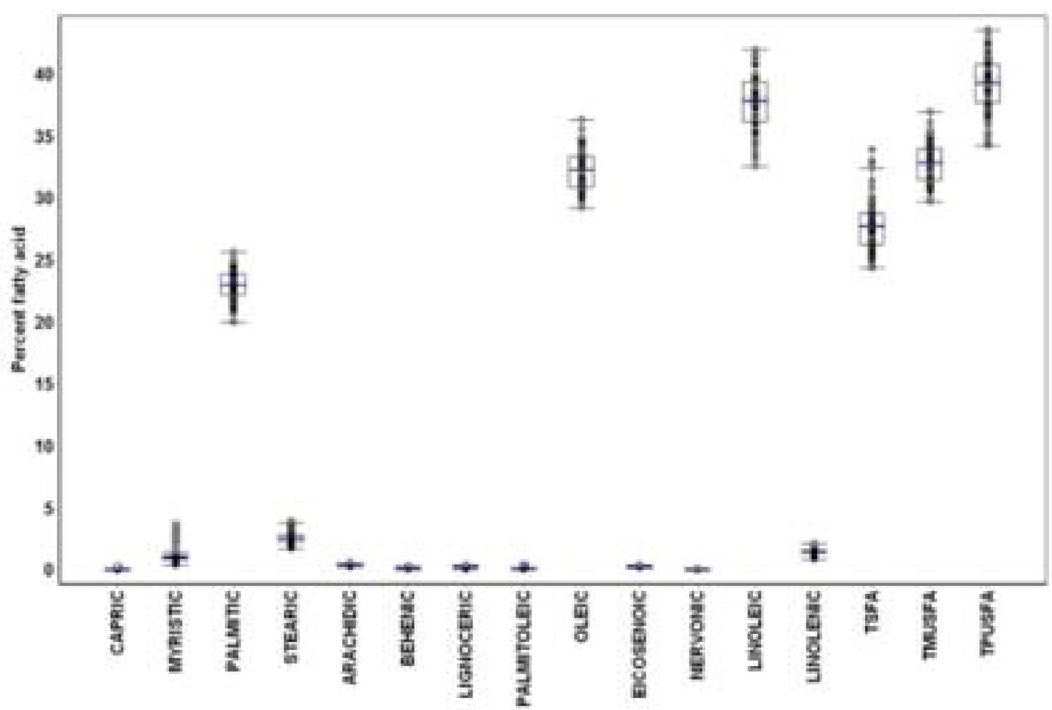
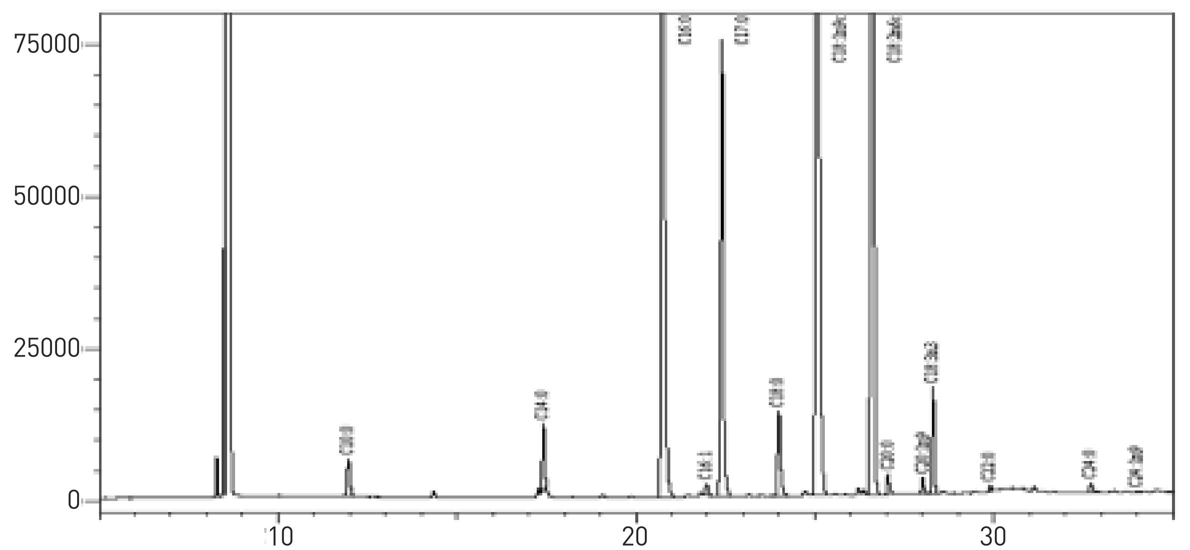


Figure 3. Fatty acids chromatogram of rice sample



using direct fatty acid methylation of samples and using SupelcoTM SP2560 column which provided clear separation of the fatty acids including Cis and Trans isomers. Low levels of arachidic (0.45 ± 0.07), behenic (0.19 ± 0.06), lignoceric (0.27 ± 0.12), nervonic (0.07 ± 0.02) and eicosenoic (0.32 ± 0.06) acids were also observed in all the rice samples studied here. Most studies on fatty acids composition in rice (Khatoon and Goapalakrishna, 2004; Mano et al, 1999; Taira and Chang 1986; Yhoshida et al, 2010; Zhou et al, 2003) failed to detect and report these minor fatty acids which together accounts for about 1.6% of the total fatty acids. The wide range of individual fatty acids in the diverse rice varieties shows that rice breeding can be designed to increase individual fatty acid of interest for improved health benefits.

Correlations were observed between many combinations of fatty acids is shown in table 6. The major fatty acid palmitic showed significant correlation with capric or myristic acids while oleic showed sig-

Table 6. Correction among the fatty acids is high yielding Indian rice varieties

	Capric	Myristic	Palmitic	Stearic	Arachidic	Behenic	Lignoceric	Palmitoleic	Oleic	Eicosenoic	Nervonic	Linoleic
Myristic	0.659**											
Palmitic	0.503**	0.454**										
Stearic	0.627**	0.493**	0.424**									
Arachidic	0.60	0.056	0.139	0.494**								
Behenic	0.348**	0.267*	0.120	0.589**	0.598**							
lignoceric	0.486**	0.206	0.057	0.473**	0.208	0.640**						
Palmitoleic	0.617**	0.858**	0.288**	0.393**	-0.061	0.330**	0.342**					
Oleic	-0.212	-0.215*	-0.316**	0.052	0.212	0.096	0.011	-0.0113				
Eicosenoic	0.323**	0.008	0.097	0.313**	0.187	0.358**	0.633**	0.138	0.184			
Nervonic	0.024	-0.318**	0.076	0.155	-0.023	0.057	0.397**	-0.251*	-0.047	0.407**		
Linoleic	-0.524**	-0.524**	-0.566**	-0.690**	-0.396**	-0.430**	-0.306**	-0.458**	-0.478**	-0.339**	0.20	
Linolenic	-0.084	-0.102	-0.083	-0.0355**	-0.243*	-0.211	-0.169	-0.117	-0.368**	-0.143	-0.137	0.352**

**. Correlation is significant at the 0.01 level) 2 tailed). *. Correlation is significant at the level (2 – tailed).

nificant negative correlation with myristic acid. Negative significant correlation was observed between linoleic acid and all other fatty acids except linolenic and nervonic acid. Palmitic acid also showed significant negative correlation with Oleic and linoleic acids. The data exhibited negative correlations between polyunsaturated fatty acids and saturated or monounsaturated.

Many important rice landraces with diverse genetic composition are grown and consumed all over the world. However, modern hybrid rice varieties have replaced the more nutritious and diverse rice varieties leading to a decline in nutrient diversity within rice species. Decline in rice diversity can adversely affects the nutrient security of the people in rice consuming populations where nutrient diversity in rice has been fundamental to the food and nutrient security of the people.

Modern biotechnology is being explored for improvement of nutrients and its bioavailability in rice, however, the purpose of using genetic engineering for food purpose is still being debated. Fortification of foods with micronutrients may have short term gains but for long term, biofortification strategy taking advantage of the consistent daily consumption of large amount of rice by all family members provides a feasible means of reaching the malnourished populations in remote areas. Increasing protein and micronutrient content like iron and zinc content in brown rice by 20% would mean a substantial increase in the protein and micronutrient intake especially in rice consuming country like India.

Conclusion

The study has revealed diverse rice varieties with wide range of nutrients within rice cultivars in India. The various agro climatic regions in India offers immense opportunity for proper selection of rice cultivars for certain regions which combine high mineral levels with low levels of inhibitors for improved bioavailability in order to combat micronutrient deficiencies in the country. The importance of nutrient diversity in rice is being understood now with the realization that biodiversity is fundamental to food and nutrient security of the people. With the sharp increase in lifestyle-related health issues and diseases, scientists should look at quality traits that place greater focus on their antioxidant properties, glycemic index, and mineral content in the vast pool of indigenous rice varieties available in the country.

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References

AOAC. (2006). Official Methods of Analysis, 18th edition, Association of Official Analytical Chemists: Gaithersburg, MD.

Banerjee, S., Chandel, G., Mandal, N., Meena, B.M. & Saluja, T. (2011). Assessment of nutritive value in milled rice grains of some Indian rice landraces and their molecular characterization. Bangladesh Journal of Agricultural Research, 36: 369–380.

Basak, S., Tyagi, R.S. & Srivastava, K.N. (2002). Biochemical characterization of aromatic and non aromatic rice cultivars. Journal of Food Science Technology (Mysore), 39: 55–58.

Brandolini, V., Coisson, J.D., Tedeschi, P., Barile, D., Cereti, E., Maietti, A., Vecchiati, G., Martelli, A. & Arlorio, M. (2006) Chemometrical characterization of four Italian rice varieties based on genetic and chemical analyses. Journal of Agricultural and Food Chemistry, 54: 9985–9991.

Chandel, G., Banerjee, S., See, S., Meena, R., Sharma, D.J. & Verulkar, S.B. (2010). Effects of different nitrogen fertilizer levels and native soil properties on rice grain Fe, Zn and protein contents. Rice Science, 17: 213–227.

Cheng, H. (1983) Total dietary fiber content of polished, brown and bran types of Japonica and Indica rice in Taiwan: Resulting physiological effects of consumption. Nutrition Research International, 13: 93–101.

Darragh, A.J. (2005). The effect of hydrolysis time on amino acid analysis. Journal of AOAC International, 88: 888–893.

Directorate of Economics and Statistics (2010). Agriculture Statistics at a glance. Department of Agriculture and cooperation, Ministry of Agriculture, Government of India, New Delhi.

FAO (2004). International year of rice 2004. Food and Agriculture Organization of the United Nations, Rome.

FAO/WHO/UNU Expert consultation (1985). Energy and protein requirements. WHO Technical Report Series No. 724. World Health Organization, Geneva, Switzerland.

Gopalan, C., Rama Sastri, B.V. & Balasubramanian, S.C. (1989). Nutritive value of Indian Foods, National Institute of Nutrition, Hyderabad – 500 007, India.

Graham, R.D., Welch, R.M., Saunders, D.A., Ortiz-Monasterio, I., Bouis, H.E., Bonierbale, M., de Haan, S., Burgos, G., Thiele, G., Liria, R., Meisner, C.A., Beebe, S.E., Potts, M.J., Kadian, M., Hobbs, P.R., Gupta, R.K. & Twomlow, S. (2007). Nutritious subsistence systems. Advance in Agronomy, 92: 1–74.

Hegsted, M. & Juliano, B.O. (1974). Difficulties in assessing the nutritional quality of rice protein. Journal of Nutrition, 104: 772–781.

Heinemann, R.J.B., Fagundes, P.L., Pinto, E.A., Penteado, M.V.C. & Lanfer-Marquez, U.M. (2005). Comparative study of nutrient composition of commercial brown, parboiled and milled rice from Brazil. Journal of Food Composition and Analysis, 18: 287–296.

Jiang, S.l., Wu, J.G., Feng, Y., Yang, X.E. & Shi, C.H. (2007). Correlation analysis of mineral element contents and quality traits in milled rice (Oryza sativa L). Journal of Agricultural and Food Chemistry, 55: 9608–9613.

Juliano, B.O. (1985). Polysaccharides, proteins and lipids of rice. In B.O. Juliano (Ed.) Rice. Chemistry and terminology (p. 59–174). St Paul, Minnesota: American Association of Cereal Chemist.

Juliano, B.O. & Bechtel, D.B. (1985) The rice grain and its gross composition. In Juliano, B.O. (Ed.) Rice Chemists and Technology, Second Ed. The American Association of Cereal Chemists, St Paul, MI, USA,

Juliano, B. & Villareal, C. (1993). Grain quality evaluation of world rices. Los Baños, Philippines, International Rice Research Institute.

Jung, M.C., Yun, S., Lee, J.S. & Lee, J.U. (2005). Baseline study on essential and trace elements in polished rice from South Korea. Environmental Geochemistry and Health, 27: 455–464.

Katcher, H.I., Legro, R.S., Kunselman, A.R., Gillies, P.J., Demers, L.M., Bagshaw, D.M. & Kris-Ethuton, P.M. (2008). The effects of a whole grain-enriched hypocaloric diet on cardiovascular disease risk factors in men and women with metabolic syndrome. American Journal of Clinical Nutrition, 87: 79–90.

Kennedy, G. & Burlingame, B. (2003). Analysis of food composition data on rice from a plant genetic resources perspective. Food Chemistry, 80: 589–596.

Khatoon, S. & Gopalakrishna, A.G. (2004). Fat soluble nutraceutical and fatty acid composition of selected Indian rice varieties. Journal of the American Oil Chemist Society, 81: 939–943.

Kim, M., Yang, H.R. & Jeong, Y. (2004). Contents of phytic acid and minerals of rice cultivars from Korea. Journal of the Korean Society of Food Science and Nutrition, 2: 301–303.

Kitta, K., Ebihara, M., Lizuka, T., Yoshikawa, R., Isshiki, K. & Kawamoto, S. (2005). Variations in lipid content and fatty acid composition of major non glutinous rice cultivars in Japan. Journal of Food Composition and Analysis, 18: 269–278.

Landry, J. & Delhaye, S. (1992). Simplified procedure for the determination of tryptophan of foods and feedstuffs from barytic hydrolysis. Journal of Agricultural and Food Chemistry, 40: 776–779.

Londo, J.P., Chiang, Y.C., Hung, K.H., Chiang, T.Y. & Schaal, B.A. (2006). Phylogeography of Asian wild rice, Oryza rufipogon, reveals multiple independent domestications of cultivated rice, Oryza sativa. Proceedings of the National Academy of Sciences. USA, 103: 9578–9583.

Mano, Y., Kawaminami, K., Kojima, M. & Ohnishi, M. (1999). Comparative composition of brown rice lipids (Lipid fractions) of indica and japonica rices. Bioscience Biotechnology and Biochemistry, 63: 619–626.

Marr, K.M., Batten, G.D. & Blakeney, A.B. (1995). Relationships between minerals in Australianbrown rice. Journal of the Science of Food and Agriculture, 68: 285–291.

Moore, S. (1963). On the determination of cystine as cysteic acid. Journal of Biological Chemistry, 238: 235–237.

NNMB (2006). Diet and nutrition status of populations and prevalence of hypertension among adults in rural areas. National Nutrition Monitoring Bureau Technical Report No. 24. National Institute of Nutrition, ICMR, Hyderabad, India.

Oatway, L., Vasanthan, T. & Helm, J.H. (2001). Phytic acid. Food Reviews International,17: 419–431.

O'Fallon, J.V., Busboom, J.R., Nelson, M.L. & Gaskins, C.T. (2007). A direct method for fatty acid methyl ester synthesis: Application to wet meat tissues, oils, and feedstuffs. Journal of Animal Science, 85: 1511–1521.

Ogiyama, S., Tagami, K. & Uchida, S. (2008). The concentration and distribution of essential elements in brown rice associated with the polishing rate: Use of ICP-AES and micro-PXE. Nuclear Instruments and Methods in Physics Research, 266: 3625–3632.

Phuong, T.D., Chuong, P.V., Tong Khiemc, D. & Kokot, S. (1999). Elemental content of Vietnamese rice. Part 1. Sampling, analysis and comparison with previous studies.The Analyst, 124: 553–560.

Roohinejad, S., Mirhosseini, H., SaariNazamid, Mustafa, S., Alias, I., Hussin, A.S.M., Hamid, A. & Manap, M.Y. (2009). Evaluation of GABA, crude protein and amino acid composition from different varieties of Malaysian's brown rice. Australian Journal of Crop Science, 3: 184–190.

Scherz, H., Senser, F. & Souci, S.W. (2000). Food composition and nutrition tables, 6th ed. CRC Press/Medpharm, Boca Raton, FL, USA, 1182 pp.

Shekar, B.P.S. & Reddy, G.M. (1982). Amino acid profiles in some scented rice varieties. Theoretical Applied Genetics, 62: 35–37.

Sotelo, A., Sousa, V., Montalvo, I., Hernandez, M. & Hernandez-

Aragon, L. (1990). Chemical composition of differentfractions of 12 Mexican varieties of rice obtained during milling. Cereal Chemistry, 67: 209–212.

Taira, H. & Chang, W.L. (1986). Lipid content and fatty acid composition of indica and japonica types of nonglutinous brown rice. Journal of Agricultural and Food Chemistry, 34: 542–545.

Tobekia, M.M., Toma, R.B. & Luh, B.S. (1981). Crude protein and amino acid composition of three California rice varieties. Nutrition Reports International, 23: 805–811.

Tucker, M.R. (1999). Essential plant nutrients: their presence in North Carolina soils and role in plant nutrition. N.C. Dep. Agric. Consumer serv. Agron. Div 9.

Villegas, R., Liu, S., Gao, Y.T., Yang, G., Li, H., Zheng, W. & Shu, X.O. (2007). Prospective study of dietary carbohydrates, glycemic index, glycemic load, and incidence of type 2 diabetes mellitus in middle-aged Chinese women. Archives of Internal Medicines, 26: 2310–6.

Wang, G., Parpia, B. & Wen, Z. (1997). The composition of Chinese foods. Institute of Nutrition and Food Hygiene Chinese Academy of Preventive Medicine. Washington DC: ILSI Press.

WHO (2002). The World Health Report 2002. Reducing Risks, Promoting Healthy Life. World Health Organization, Geneva, Switzerland.

Yoshida, H., Tomiyama, Y. & Mizushina, Y. (2010). Lipid components, fatty acids and triacylglycerol molecular species of black rice and red rices. Food Chemistry, 123: 210–215.

Zeng, Y., Wang, L., Du, J., Liu, J., Yang, S., Pu, X. & Xiao, F. (2009) Elemental content in Brown Rice by Inductively Coupled Plasma Atomic Emission spectroscopy Reveals the Evolution of Asian Cultivated Rice. Journal of Integrative Plant Biology 2009, 51: 466–475.

Zhai, C.K., Lu, C.M., Zhang, X.Q., Sun, G.J. & Lorenz, K.J. (2001). Comparative study on the nutritional value of Chinese and North American wild rice. Journal of Food Composition and Analysis, 14: 371–382.

Zhou, Z., Blanchard, C., Helliwell, S. & Robards, K. (2003). Fatty acid composition of three rice varieties following storage. Journal of Cereal Science, 37: 327–335.

CANARIUM ODONTOPHYLLUM MIQ.: AN UNDERUTILIZED FRUIT FOR HUMAN NUTRITION AND SUSTAINABLE DIETS

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Abstract
Canarium odontophyllum Miq. or locally known as "dabai", is one of the popular underutilized fruits of Sarawak, Malaysia. Local community consumes a significant amount of dabai during the fruiting season without much knowledge about its nutritional composition and health-promoting properties. Nutritional composition and antioxidant properties of dabai fruits from different growing areas in Sarawak were investigated. Lipid was the major macronutrient in dabai fruit, while the predominant minerals were magnesium and calcium. The fruit is a source of unsaturated fatty acids, with 38–42% oleic acid, 15–18% linoleic acid and traces of linolenic acid. The total anthocyanin content in dabai fruit (2.05–2.49 mg/g dried weight) was comparable to blackberry, blueberry and grape. Fifteen types of phenolic compounds have been identified from this fruit. Several products like mayonnaise, sauces, chips, pickles and soap have been developed from this fruit. This fruit has also been used by local restaurants as an ingredient in their dishes.

1. Introduction

The Food and Agriculture Organization of the United Nations (FAO) in its effort working with its members and the entire international community for achievement of the Millennium Development Goals (MDGs), has declared year 2010 as the International Year of Biodiversity. The integration of biodiversity and nutrition is important for the achievement of MDGs. With this, the conservation and sustainable use of biodiversity for food and agriculture play a critical role in the fight against hunger, by ensuring environmental sustainability while increasing food production.

Sarawak has the richest diversity of flora in Malaysia and offers an excellent source of indigenous fruits and vegetables to the rural communities. *Canarium odontophyllum* Miq. is one of the popular indigenous fruits potentially to be developed as a speciality fruit of Sarawak. The fruit is known as "dabai" among the local community and has been dubbed "Sibu olive" because of its physical appearance, smooth texture and rich flavour (Lau and Fatimah, 2007). Dabai fruits are similar in appearance to olive fruits and turn dark purple when they are fully ripe. The fruits are ovoid drupes, weigh 10.0–18.0 g, 3.0–4.0 cm long and 2.2–3.0 cm in diameter. Dabai fruit contains a single seed with hard and thick endocarp (2.5–3.5 cm long and 1.6–2.0 cm in diameter). The seed is sub-triangular with three chambers. The purple peel and pale yellow fleshy pulp of this fruit (3.0–5.0 mm thick) is edible, while the seed is discarded. The whole ripe fruit is soaked in warm water for 3–5 minutes to soften the pulp and eaten as such or with sugar, salt, pepper or sauce. Dabai fruits are traditionally consumed as highly nutritious fruit rich in energy and fat by local community during fruiting season.

Dabai fruits are rarely eaten, unfamiliar and unknown elsewhere apart from Sarawak. They are sometimes viewed by outsiders as nutritionally inferior fruit. The current usage of dabai fruits is still limited to human consumption. Therefore, there is an urge for scientific evidence to realize the full potential of dabai fruits. To the best of our knowledge, only few reports on nutritional composition and antioxidant properties of dabai fruits are available. Voon and Kueh (1999) has reported the proximate composition including mineral and vitamin content of dabai fruit, while oils extracted from the fruit pulp and kernel were studied for their fatty acids composition and vitamin E content by Azlan *et al.* (2010). Carotenoids profiles of peel, pulp and seed of the fruit and their related antioxidant capacities have been studied by Prasad *et al.* (2011). Extracts of peel, pulp and kernel of dabai fruit have consistently shown antioxidant capacities (Azrina *et al.*, 2010; Prasad *et al.*, 2010; Shakirin *et al.*, 2010).

Previous studies have indicated that geographical conditions and botanical aspects such as variety can significantly affect nutritional values and health beneficial attributes of fruits qualitatively and quantitatively. Influence of geographical conditions on the nutritional composition and antioxidant properties of dabai fruits is unknown. Moreover, apparently there are two varieties of dabai fruits found: the commonly available purple dabai fruit and the less common red dabai fruit. This study was therefore designed to determine and compare the nutritional composition and antioxidant properties of dabai fruits from different divisions of Sarawak, as well as between the two varieties. Thus, this study plays a significant part in the achievement of the MDGs, especially to eradicate extreme poverty and hunger (Goal 1) and to ensure environmental sustainability (Goal 7) in developing countries like Malaysia. This study contributes to the enhancement of livelihood and income of the rural poor. Scientific evidence for the health benefits of dabai fruits in addition to their nutritional quality will provide added value to the fruits. Moreover, this study contributes to the mitigation of environmental degradation by conserving and safeguarding the genetic resources with sustainable use of the natural resources.

2. Proximate composition

Proximate composition (g/100 g FW) of dabai fruits from different growing areas is given in Table 1. Lipid was the major macronutrient of dabai fruits and did not differ among fruits from different growing areas (21.16–25.76 g/100 g FW). Moisture accounted for 50.44–51.91 percent by FW while ash content was 1.66–1.89 g/100 g FW. Both moisture and ash contents did not differ among dabai fruits collected from different growing areas. Results also demonstrated that the red variety showed no difference from the purple variety in terms of their lipid, moisture and ash contents.

Table 1. Nutritional composition of dabai fruits from different growing areas.

Nutritional composition*	Purple dabai fruits			Red dabai fruits
	Kanowit	Kapit	Song	Sarikei
Moisture	51.30±0.93a (50.13–52.97)	51.11±1.10a (49.26–53.08)	50.44±0.76a (48.78–51.70)	51.91±0.88a (50.92–52.60)
Total available carbohydrate	4.45±0.83b (3.57–5.50)	5.07±0.82b (3.89–5.84)	8.97±2.21a (6.11–12.51)	9.16±0.15a (8.99–9.27)
Protein	5.20±0.87a (3.75–6.22)	4.56±0.87a,b (3.08–5.65)	4.35±1.15a,b (2.69–6.68)	3.45±0.64b (2.78–4.04)
Lipid	25.76±3.03a (22.30–29.51)	21.16±4.71a (14.57–26.01)	24.47±2.76a (20.91–29.04)	23.72±1.11a (23.08–25.01)
Ash	1.89±0.08a (1.77–1.95)	1.88±0.42a (1.46–2.42)	1.66±0.26a (1.34–2.00)	1.78±0.17a (1.66–1.90)

*g/100 g fresh weight. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at $p \leftarrow 0.05$ within the same row.

Table 2. Minerals composition of dabai fruits from different growing area.

Minerals*	Kanowit	Purple dabai fruits Kapit	Song	Red dabai fruits Sarikei
Magnesium	80.31±3.97a (76.51–84.51)	74.67±15.36a (56.26–93.23)	76.09±24.07a (50.04–102.07)	62.72±0.38a (62.38–63.25)
Calcium	28.47±1.56a (26.87–30.08)	40.52±16.66a (22.90–61.94)	43.72±22.72a (16.00–67.88)	40.60±0.11a (40.50–40.74)
Sodium	8.77±0.34b (8.47–9.50)	12.05±3.45a (7.26–15.91)	10.77±0.31a,b (10.13–11.19)	9.36±0.05b (9.28–9.41)
Potassium	6.80±0.21a,b (6.50–7.19)	6.93±1.71a (4.84–9.06)	5.29±1.10b,c (3.64–6.76)	5.02±0.13c (4.85–5.16)
Iron	3.10±0.49a (2.58–3.60)	3.14±0.26a (2.76–3.44)	2.10±0.09b (1.93–2.18)	2.80±0.04a (2.76–2.84)
Zinc	0.78±0.18b (0.61–0.95)	0.81±0.05a,b (0.74–0.86)	0.77±0.09b (0.66–0.87)	0.92±0.01a (0.91–0.93)
Copper	0.47±0.06a (0.42–0.53)	0.35±0.14 (0.24–0.55)	0.39±0.04aa (0.32–0.44)	0.21±0.00b (0.20–0.21)

*mg/100 g fresh weight. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at p ← 0.05 within the same row.

Protein content varied to a greater extent among dabai fruits. While the highest protein content was found in purple dabai fruits from Kanowit (5.20 g/100 g FW), the lowest was in red dabai fruits from Sarikei (3.45 g/100 g FW). It was observed that total available carbohydrate content in the red variety and in purple dabai fruits from Song (9.16 and 8.97 g/100 g FW, respectively) were almost twofold higher than purple dabai fruits from Kapit and Kanowit (5.07 and 4.45 g/100 g FW, respectively). Red dabai fruits were richer in available carbohydrate but with reduced amount of protein as compared to the purple variety.

3. Mineral composition

Mineral composition of dabai fruits varied considerably from one division to another, as well as varying between the red and purple varieties (Table 2). The predominant minerals in dabai fruits were magnesium (62.72–80.31 mg/100 g FW), calcium (28.47–43.72 mg/100 g FW), sodium (8.77–12.05 mg/100 g FW) and potassium (5.02–6.93 mg/100 g FW). Iron, zinc and copper were detected in appreciable amounts in dabai fruits of the present study. It was noted that dabai fruits from Kapit distinguishably had the highest contents of sodium, potassium and iron in every 100 g FW of fruits.

4. Amino acids composition

The amino acids composition of dabai fruits is given in Table 3. Considerable variation was observed from one growing area to another; similarly, variation was

Table 3. Amino acids composition of dabai fruits from different growing areas.

	Purple dabai fruits			Red dabai fruits
Amino acids*	Kanowit	Kapit	Song	Sarikei
Essential				
Isoleucine	2.64±0.13a (2.51–2.75)	2.39±0.29a (1.99–2.69)	2.55±0.07a (2.43–2.63)	2.75±0.11a (2.67–2.83)
Leucine	7.40±0.30a (6.95–7.62)	7.24±1.07a (6.13–8.80)	7.29±0.42a (6.64–7.78)	8.23±0.29a (8.02–8.43)
Lysine	5.61±0.22a (5.38–5.91)	5.43±0.78a (4.32–6.14)	5.86±0.28a (5.49–6.41)	5.77±0.16a (5.65–5.88)
Methionine	0.90±0.01b (0.89–0.92)	0.91±0.09b (0.81–1.04)	0.95±0.07a,b (0.85–1.04)	1.09±0.08a (1.03–1.15)
Phenylalanine	4.82±0.16a (4.65–4.95)	4.64±0.65a (3.61–5.29)	5.16±0.35a (4.71–5.64)	5.09±0.44a (4.78–5.40)
Threonine	3.39±0.06a (3.30–3.43)	3.24±0.34a (2.69–3.64)	3.84±0.55a (3.35–5.04)	3.64±0.17a (3.52–3.76)
Valine	3.66±0.21a (3.41–3.84)	3.07±0.34a (2.70–3.62)	3.57±0.39a (2.73–4.02)	3.60±0.24a (3.43–3.77)
Non-essential				
Alanine	4.93±0.21a (4.79–5.25)	4.82±0.51a (4.21–5.55)	5.12±0.56a (4.56–6.13)	4.89±0.30a (4.68–5.10)
Arginine	2.54±0.17a (2.31–2.66)	3.15±0.54a (2.52–3.83)	2.87±0.05a (2.81–2.95)	2.82±0.07a (2.77–2.87)
Aspartic acid	27.18±1.33a (26.24–29.06)	30.91±6.05a (25.43–40.14)	26.37±1.93a (22.65–28.83)	25.34±0.11a (25.26–25.41)
Cystine	0.60±0.19a (0.40–0.76)	0.75±0.27a (0.44–1.09)	0.63±0.50a (0.10–1.55)	0.32±0.45a (0.10–0.63)
Glutamic acid	19.58±0.34a (19.29–19.90)	18.32±1.18a (16.64–19.44)	19.01±0.65a (18.18–19.89)	19.61±0.55a (19.22–20.00)
Glycine	4.32±0.17a (4.10–4.52)	3.94±0.46a (3.25–4.55)	4.44±0.39a (4.05–5.21)	4.32±0.16a (4.20–4.43)
Histidine	2.37±0.14a (2.16–2.46)	2.02±0.21b (1.76–2.31)	2.28±0.13a,b (2.12–2.48)	2.39±0.17a (2.27–2.51)
Proline	4.29±0.17a (4.12–4.52)	4.40±0.55a (3.57–4.99)	4.68±0.37a (4.21–5.30)	4.73±0.23a (4.57–4.89)
Serine	2.89±0.43a (2.49–3.26)	2.41±0.14a (2.23–2.57)	2.62±0.30a (2.31–3.04)	2.72±0.01a (2.71–2.72)
Tyrosine	2.90±0.10a (2.79–2.98)	2.38±0.31b (1.96–2.64)	2.79±0.11a (2.63–2.97)	2.73±0.17a,b (2.61–2.85)

*% of total amino acids. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at p ← 0.05 within the same row.

noted between the two varieties investigated. Seventeen amino acids were detected, including seven essential (isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine) and ten non-essential (alanine, arginine, aspartic acid, cystine, glutamic acid, glycine, histidine, proline, serine and tyrosine) amino acids. Fruits were especially rich in aspartic and glutamic acids, constituting 44.95–49.23 percent of total amino acids. Essential aminoacids were present at lower concentrations (26.9–30.2%), of which methionine was the limiting amino acid (0.90–1.09%).

5. Fatty acids composition

Dabai fruit pulp oil contained mainly palmitic (37.1–39.5%), stearic (1.3–3.7%), oleic (38.1–42.4%) and linoleic (15.3–18.4%) acids (Table 4). The oil was a source of unsaturated fatty acids (57.94–59.08%).

Table 4. Fatty acids composition of dabai fruits from different growing areas.

	Purple dabai fruits			Red dabai fruits
Fatty acids*	Kanowit	Kapit	Song	Sarikei
C14:0 Myristic acid	0.23±0.03a,b (0.21–0.26)	0.20±0.01b (0.20–0.21)	0.21±0.04b (0.17–0.27)	0.28±0.00a (0.28–0.28)
C16:0 Palmitic acid	38.15±0.76a (37.48–38.82)	37.12±0.45a (36.54–37.48)	38.11±3.18a (34.39–42.67)	39.48±0.01a (39.47–39.48)
C17:0 Margaric acid	0.03±0.00a (0.03–0.03)	0.03±0.00a (0.03–0.03)	0.03±0.00a (0.03–0.04)	0.04±0.01a (0.03–0.04)
C18:0 Stearic acid	2.72±0.26b (2.50–2.95)	3.51±0.15a,b (3.41–3.70)	3.68±0.63a (3.19–4.68)	1.33±0.00c (1.33–1.33)
C24:0 Lignoceric acid	0.03±0.01b (0.02–0.03)	0.05±0.01a (0.04–0.06)	0.03±0.01a,b (0.01–0.05)	0.04±0.02a,b (0.02–0.05)
SFA	**41.16±0.53a (40.69–41.63)**	**40.92±0.54a (40.23–41.36)**	**42.06±2.69a (39.29–46.13)**	**41.16±0.04a (41.13–41.18)**
C16:1 Palmitoleic acid	0.76±0.12b (0.66–0.86)	0.76±0.07b (0.67–0.80)	0.62±0.12b (0.48–0.79)	1.69±0.00a (1.69–1.69)
C18:1 n9c Oleic acid	41.04±0.70a,b (40.43–41.65)	42.36±0.22a (42.10–42.61)	40.88±3.06a,b (36.78–44.79)	38.06±0.01b (38.05–38.07)
C20:1 Eicosenoic acid	0.03±0.00a,b (0.03–0.03)	0.04±0.01a (0.03–0.04)	0.04±0.01a (0.03–0.05)	0.02±0.00b (0.02–0.02)
MUFA	**41.83±0.58a (41.32–42.34)**	**43.15±0.28a (42.81–43.45)**	**41.54±3.02a (37.47–45.32)**	**39.77±0.01a (39.76–39.78)**
C18:2 n6c Linoleic acid	16.40±0.01b (16.38–16.41)	15.30±0.34b (14.96–15.72)	15.73±1.24b (14.55–17.60)	18.40±0.04a (18.37–18.43)
C18:3 n6 Linolenic acid	0.58±0.05a (0.54–0.62)	0.60±0.03a (0.57–0.64)	0.64±0.12a (0.49–0.80)	0.67±0.01a (0.66–0.67)
C18:3 n3 Linolenic acid	0.03±0.00a (0.03–0.03)	0.03±0.01a (0.02–0.03)	0.03±0.00a (0.03–0.03)	0.02±0.00b (0.02–0.02)
PUFA	**17.01±0.06b (16.95–17.06)**	**15.93±0.32b (15.62–16.33)**	**16.40±1.13b (15.38–18.12)**	**19.09±0.04a (19.06–19.11)**

*% of total fatty acids. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at p ← 0.05 within the same row.

Almost even proportion of saturated fatty acids (40.9–42.1%) and monounsaturated fatty acids (39.8–43.2%) was observed. Results of the present study are in good agreement with that of Azlan *et al.* (2010) which the ratio of saturated (SFA): monounsaturated (MUFA): polyunsaturated (PUFA) fatty acids reported was 44.4: 42.8: 12.8. A notable finding was that the percentage of PUFA in red dabai fruits from Sarikei (19.1%) was higher than the purple variety (15.9–17.0%).

6. Phenolic constituents

Total phenolics content and TFC of dabai fruits were found to be varied from one growing area to another; and significantly different between the red and purple varieties. Purple dabai fruits collected from Kapit had the significantly highest TPC and TFC ($p < 0.01$), while the significantly lowest TPC and TFC ($p < 0.01$) were found in red dabai fruits. The TPC of purple dabai fruits from Kapit was three times higher than red dabai fruits. Purple dabai fruits from Kapit also had the TFC which was five times higher than red dabai fruits. It was observed that cooking the fruits at 60°C for 3–5 minutes resulted in increases of TPC and TFC (Tables 5 and 6).

Dabai fruits from Kapit, Kanowit and Song were all of the purple variety, formed a homogeneous group with no significant difference in their TAC, ranged 2.05–2.49 mg anthocyanins pigment/g DW.

In contrast, red dabai fruits from Sarikei had the significantly lowest TAC (0.08 mg anthocyanins pigment/g DW) ($p < 0.01$). Contrarily to the previous two observations, cooking of dabai fruits at 60°C for 3–5 minutes resulted in decreases of TAC (Table 7).

Table 5. Total phenolics content of dabai fruits from different growing areas.

		Purple dabai fruits		Red dabai fruits
TPC	Kanowit¥	Kapit¥	Song¥	Sarikei
Cooked fruit	19.44±2.90b (15.40–22.01)	33.21±6.11a (27.25–42.57)	22.81±5.91b (15.11–32.13)	9.50±0.42c (9.17–9.97)
Uncooked fruit	13.79±1.18b (12.38–15.59)	27.02±5.20a (22.24–33.97)	14.12±3.97b (10.95–21.02)	9.10±1.20b (8.18–10.46)

TPC, total phenolics content expressed as mg gallic acid equivalent (GAE)/g dried weight. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at p ← 0.05 within the same row.
¥ indicates significantly different at p ← 0.05 within the same column.

Table 6. Total flavonoids content of dabai fruits from different growing areas.

		Purple dabai fruits		Red dabai fruits
TFC	Kanowit¥	Kapit	Song¥	Sarikei
Cooked fruit	55.46±9.11b (44.38–67.14)	103.92±24.60a (76.24–139.33)	53.31±12.15b (31.10–70.29)	20.46±5.62c (14.81–26.05)
Uncooked fruit	33.06±5.60b (28.24–41.10)	86.06±21.71a (62.38–122.71)	37.59±16.03b (22.62–73.00)	14.08±3.23b (12.10–17.81)

TFC, total flavonoids content expressed as mg rutin equivalent (RE)/g dried weight. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at p ← 0.05 within the same row.
¥ indicates significantly different at p ← 0.05 within the same column.

Table 7. Total anthocyanins content of dabai fruits from different growing areas.

	Purple dabai fruits			Red dabai fruits
TAC	Kanowit	Kapit¥	Song¥	Sarikei¥
Cooked fruit	2.06±0.53a (1.49–2.74)	2.49±0.60a (1.73–3.41)	2.05±0.30a (1.55–2.51)	0.08±0.00b (0.08–0.09)
Uncooked fruit	2.54±0.25a (2.32–2.81)	3.54±0.94a (2.29–4.61)	3.20±0.83a (2.45–4.69)	0.18±0.01b (0.17–0.18)

TAC, total anthocyanins content expressed as mg anthocyanins pigment/g dried weight. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at $p \leftarrow 0.05$ within the same row.
¥ indicates significantly different at $p \leftarrow 0.05$ within the same column.

Table 8. Trolox equivalent antioxidant capacity of dabai fruits from different growing areas.

	Purple dabai fruits			Red dabai fruits
TEAC	Kanowit¥	Kapit¥	Song¥	Sarikei¥
Cooked fruit	0.45±0.05b (0.40–0.50)	0.68±0.09a (0.57–0.85)	0.38±0.06b (0.31–0.47)	0.20±0.00c (0.20–0.21)
Uncooked fruit	0.21±0.04b,c (0.17–0.24)	0.32±0.04a (0.28–0.39)	0.25±0.03b (0.20–0.30)	0.18±0.01c (0.18–0.19)

TEAC, trolox equivalent antioxidant capacity expressed as mmol trolox equivalent (TE)/g dried weight. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at $p \leftarrow 0.05$ within the same row.
¥ indicates significantly different at $p \leftarrow 0.05$ within the same column.

Table 9. Ferric reducing ability of dabai fruits from different growing areas.

	Purple dabai fruits			Red dabai fruits
FRAP	Kanowit¥	Kapit¥	Song¥	Sarikei¥
Cooked fruit	0.93±0.30b (0.65–1.35)	1.74±0.32a (1.31–2.05)	1.08±0.31b (0.79–1.64)	0.27±0.02c (0.26–0.29)
Uncooked fruit	0.03±0.01b (0.01–0.04)	0.50±0.15a (0.35–0.74)	0.08±0.09b (0.00–0.25)	0.02±0.01b (0.01–0.02)

FRAP, ferric reducing ability expressed as mmol of Fe2+/g dried weight. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at $p \leftarrow 0.05$ within the same row.
¥ indicates significantly different at $p \leftarrow 0.05$ within the same column.

7. Antioxidant capacities

Trolox equivalents antioxidant capacities were found different among fruits from different growing areas; and between the red and purple dabai fruits. Dabai fruits collected from Kapit exhibited the highest TEAC ($p < 0.01$). The significantly lowest TEAC ($p < 0.01$) was found in red dabai fruits. The TEAC of fruits increased after fruits were cooked at 60°C for 3–5 minutes (Table 8). The FRAP values of dabai fruits indicated differences among fruits from different divisions; and differed between the red and purple varieties. While the significantly highest FRAP value ($p < 0.01$) was found in purple dabai fruits from Kapit, the significantly lowest ($p < 0.01$) was of red dabai fruits. Similarly, cooking of the fruits at 60°C for 3–5 minutes resulted in increases of FRAP values (Table 9).

Table 10. DPPH radicals scavenging activity of dabai fruits from different growing areas.

DPPH	Purple dabai fruits Kanowit¥	Kapit¥	Song¥	Red dabai fruits Sarikei
Cooked fruit	89.45±0.50a,b (88.85–90.08)	88.14±1.21b (85.84–89.57)	88.12±1.09b (85.80–88.94)	90.96±0.22a (90.80–91.21)
Uncooked fruit	71.22±3.34b (66.74–74.84)	58.96±7.89c (51.44–70.91)	64.59±8.30b,c (49.27–72.35)	91.03±0.03a (91.01–91.0

DPPH, DPPH radicals scavenging activity expressed as percentage of inhibition. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at p ← 0.05 within the same row.
¥ indicates significantly different at p ← 0.05 within the same column.

All dabai fruits exhibited high DPPH free radicals scavenging activities of more than 88 percent, indicating good potential as free radicals scavengers. The hierarchy of dabai fruits with respect to their abilities to scavenge DPPH free radicals was red dabai fruits > purple dabai fruits from Kanowit > purple dabai fruits from Kapit > purple dabai fruits from Song. Cooking of fruits at 60°C for 3–5 minutes also resulted in increases of DPPH free radicals scavenging activity (Table 10). Interestingly, red dabai fruits from Sarikei with lowest TEAC and FRAP value demonstrated the greatest DPPH free radicals scavenging activity.

Purple dabai fruits from Kapit that were found to possess significantly the highest TPC, TFC and TAC exhibited significantly the greatest TEAC and FRAP. Similarly, significantly the lowest TEAC and FRAP were observed in red dabai fruits from Sarikei which had significantly the least TPC, TFC and TAC. These data suggest that phenolic compounds (including flavonoids and anthocyanins) in dabai fruits provide substantial antioxidant activities. It is strongly believed that the antioxidant properties of purple dabai fruits from Kapit are intimately related to the geographical location of Kapit. It is a remote division of Sarawak, with less exposure to pollutants which could have a positive effect on the phytochemical properties of dabai fruits cultivated in Kapit.

Further data analysis indicated very strong linear correlations between TPC and TEAC (r = 0.958), and between TPC and FRAP (r = 0.999). Similarly, very strong linear correlations between TFC and TEAC (r = 0.991), and between TFC and FRAP (r = 0.983) were noted. Strong linear correlations between TAC and TEAC (r = 0.870), and between TAC and FRAP (r = 0.906) were also observed. Due to the lower correlations of TAC with TEAC and FRAP values, we could say that anthocyanins did not play a major role in antioxidant mechanisms with these tests. Moderate to strong negative correlations were found between TPC and DPPH (r = -0.898), between TFC and DPPH (r = -0.794) and between TAC and DPPH (r = -0.912).

8. Phenolic compounds

In the present study, the chromatographic profiles of phenolic acids and flavonoids in dabai fruits were qualitatively similar for the two varieties (purple and red dabai fruits). However, they differed in the amount of phenolic compounds identified. The chromatographic profile of anthocyanidins and anthocyanins in dabai fruits revealed marked differences between varieties, with more phenolics in purple dabai fruits. Anthocyanidins and anthocyanins were relatively more abundant in purple dabai fruits.

Catechin was the major phenolic compound in dabai fruits. Catechin in red dabai fruits (0.33 mg/g DW)

Table 11. Contents of phenolic acids and flavonoids in dabai fruits from different growing areas.

	Purple dabai fruits			Red dabai fruits
Phenolic compound	Kanowit	Kapit	Song	Sarikei
Catechin	3.01±0.06b (2.93–3.08)	4.00±0.58a (3.31–4.69)	3.22±0.29a,b (2.84–3.64)	0.33±0.02c (0.31–0.34)
Epigalocatechin gallate	0.28±0.01a (0.27–0.29)	0.25±0.06a (0.16–0.30)	0.24±0.04a,b (0.21–0.29)	0.16±0.01b (0.15–0.16)
Epicatechin	0.09±0.01a (0.08–0.10)	0.10±0.04a (0.05–0.14)	0.08±0.01a (0.06–0.10)	0.07±0.00a (0.07–0.07)
Epicatechin gallate	0.04±0.01a,b (0.04–0.05)	0.05±0.01a (0.03–0.06)	0.03±0.01a,b (0.02–0.04)	0.03±0.00b (0.03–0.03)
Apigenin	0.09±0.01a,b (0.08–0.10)	0.12±0.02a (0.11–0.14)	0.08±0.02b (0.05–0.10)	0.08±0.00b (0.08–0.08)
Ellagic acid	0.09±0.02a (0.07–0.11)	0.21±0.11a (0.08–0.34)	0.16±0.07a (0.10–0.27)	0.10±0.01a (0.09–0.10)
Vanilic acid	0.01±0.00a,b (0.01–0.01)	0.02±0.01a (0.01–0.02)	0.01±0.00a,b (0.01–0.02)	0.01±0.00b (0.01–0.01)
Ethyl gallate	0.02±0.00b (0.01–0.02)	0.03±0.01a (0.02–0.03)	0.01±0.00b (0.01–0.02)	0.01±0.00b (0.01–0.01)

mg/g DW. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at $p \leftarrow 0.05$ within the same row.

was significantly lower than purple dabai fruits (3.01 to 4.00 mg/g DW) ($p < 0.01$); while the content of other identified phenolic compounds was comparable in both varieties. Epigalocatechin gallate, epicatechin, epicatechin gallate, apigenin and ellagic acid were all present in appreciable amounts, while vanilic acid and ethyl gallate were relatively lower (Table 11). Cyanidin-3-O-rutinoside was the major anthocyanin with its content been 16 and 26 times higher in purple variety than red variety. Cyanidin and its glycosides (cyanidin-3-O-glucoside and cyanidin-3-O-rutinoside) were the main anthocyanidins and anthocyanins detected in both varieties; with trace amount of pelargonidin. In addition, delphinidin, malvidin-3,5-di-O-glucoside at appreciable amount and trace of peonidin-3-O-glucoside were also detected in purple dabai fruits (Table 12).

Within the same variety, in purple dabai fruits, considerable variability in the content of all identified phenolic compounds from one division to another was noted. Tura *et al*. (2007) reported a similar observation that the phenolic compounds content of olive fruits was influenced by site of cultivation/growing environment. Dabai fruits collected from Kapit clearly exhibited the highest content of almost all the identified phenolic acids and flavonoids. Similarly, dabai fruits possessed the highest content of all identified anthocyanidins and anthocyanins were collected from Kapit. It is noted that the total flavanols content of purple dabai fruits was much higher than apple, blackberry, blueberry, black grape, raspberry and strawberry (Arts *et al.*,

Table 12. Contents of anthocyanidins and anthocyanins in dabai fruits from different growing areas.

Phenolic compound	Kanowit	Purple dabai fruits Kapit	Song	Red dabai fruits Sarikei
Cyanidin	0.06±0.01a (0.06–0.07)	0.07±0.01a (0.05–0.08)	0.06±0.01a (0.05–0.08)	0.03±0.00b (0.03–0.03)
Cyanidin-3-O-glucoside	0.34±0.02a (0.31–0.37)	0.39±0.07a (0.29–0.46)	0.32±0.07a (0.25–0.41)	0.03±0.00b (0.03–0.03)
Cyanidin-3-O-rutinoside	1.16±0.03b (1.13–1.19)	1.85±0.34a (1.49–2.27)	1.41±0.13b (1.31–1.63)	0.07±0.00c (0.07–0.07)
Delphinidin	0.02±0.00b (0.01–0.02)	0.11±0.03a (0.08–0.16)	0.04±0.03b (0.01–0.08)	ND
Malvidin-3,5-di-O-glucoside (0.03-0.15)	0.07±0.02b (0.05–0.10)	0.20±0.07a (0.12–0.28)	0.09±0.04b	ND
Pelargonidin	Tr	Tr	Tr	Tr
Peonidin-3-O-glucoside	Tr	Tr	Tr	ND

Tr, trace; ND, not detected (← 10 ng/injection (20μl)).
mg/g DW. Results are expressed in mean±SD and (range).
Values with different letters are significantly different at p ← 0.05 within the same row.

2000; de Pascual-Teresa and Sanchez-Ballesta, 2008; Tsanova-Savova *et al.*, 2005) while the total anthocyanins content was comparable among them.

9. Conclusions

All data obtained revealed that dabai fruit was a very nutritious fruit. While the proximate, amino acids and fatty acids compositions of dabai fruits varied to a lesser extent among fruits from different growing areas as well as between the red and purple varieties; total phenolics (TPC), flavonoids (TFC) and anthocyanins (TAC) contents of fruits were found varied greatly among growing areas and especially between the two varieties. Dabai fruit had high nutritional values and great antioxidant properties; exhibiting huge potential of extrapolation. It is postulated that, in addition to the beneficial effects conferred by its unsaturated fatty acids on blood lipids profile by lowering blood cholesterol and triglyceride levels, phenolic compounds of dabai fruit give positive effects against oxidative stress. The numerous potential biological capabilities of dabai fruits based on the specific phenolic compounds identified, such as the cardioprotective effects of anthocyanins and antidiabetic effects of flavanols deserve more precise and specific further investigations. Considering that little or no information is available about the four divisions under investigation including their soils, rainfall and other important variables, further studies to achieve this purpose need to be conducted especially in Kapit, a division where dabai fruits collected distinguishably having great antioxidant properties. Moreover, based on the knowledge obtained in this study on the variability between the purple and red varieties, further investigation is needed to make the best use of the two varieties.

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References

Arts, I. C. W., van de Putte, B., Hollman, P. C. H. (2000). Catechin contents of foods commonly consumed in the Netherlands. 1. Fruits, vegetables, staple foods, and processed foods. Journal of Agricultural and Food Chemistry, 48, 1746-1751.

Azlan, A., Prasad, K. N., Khoo, H. E., Abdul-Aziz, N., Mohamad, A., Ismail, A., Amom, Z. (2010). Comparison of fatty acids, vitamin E and physicochemical properties of Canarium odontophyllum Miq. (dabai), olive and palm oils. Journal of Food Composition and Analysis, 23, 772-776.

Azrina, A., Nurul Nadiah, M. N., Amin, I. (2010). Antioxidant properties of methanolic extract of Canarium odontophyllum fruit. International Food Research Journal, 17, 319-326.

de Pascual-Teresa, S., & Sanchez-Ballesta, M. T. (2008). Anthocyanins: from plant to health. Phytochemistry Reviews, 7, 281-299.

Lau, C. Y., & Fatimah, O. (2007). Cold storage of dabai fruit (Canarium odontophyllum Miq.): Effect of Packaging methods and storage duration on quality. In Proceedings of the Technical Session, Research Officers' Conference. Department of Agriculture: Sarawak, Malaysia.

Prasad, K. N., Chew, L. Y., Khoo, H. E., Bao, Y., Azlan, A., Amin, I. (2011). Carotenoids and antioxidant capacities from Canarium odontophyllum Miq. fruits. Food Chemistry, 124, 1549-1555.

Prasad, K. N., Chew, L. Y., Khoo, H. E., Kong, K. W., Azlan, A., Ismail, A. (2010). Antioxidant capacities of peel, pulp, and seed fractions of Canarium odontopyllum Miq. fruit. Journal of Biomedicine and Biotechnology, 2010, 871379.

Shakirin, F. H., Prasad, K. N., Ismail, A., Yuon, L. C., Azlan, A. (2010). Antioxidant capacity of underutilized Malaysian Canarium odontophyllum (Dabai) Miq. fruit. Journal of Food Composition and Analysis, 23, 777-781.

Tsanova-Savova, S., Ribarova, F., Gerova, M. (2005). (+)-Catechin and (−)-epicatechin in Bulgarian fruits. Journal of Food Composition and Analysis, 18, 691-698.

Tura, D., Gigliotti, C., Pedò, S., Failla, O., Bassi, D., Serraiocco, A. (2007). Influence of cultivar and site of cultivation on levels of lipophilic and hydrophilic antioxidants in virgin olive oils (Olea Europea L.) and correlations with oxidative stability. Scientia Horticulturae, 112, 108-119.

Voon, B. H., & Kueh, H. S. (1999). The nutritional value of indigenous fruits and vegetables in Sarawak. Asia Pacific Journal of Clinical Nutrition, 8(1), 24-31.

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IMPROVED MANAGEMENT, INCREASED CULTURE AND CONSUMPTION OF SMALL FISH SPECIES CAN IMPROVE DIETS OF THE RURAL POOR

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Abstract
In many low-income countries with water resources, small fish species are important for the livelihoods, nutrition and income of the rural poor. The small size of fish favours frequent consumption by and nutrition of the rural poor, as these fish are captured, sold and bought in small quantities; used both raw and processed in traditional dishes; and are nutrient-rich. All small fish species are a rich source of animal protein, and – as they are eaten whole – have a very high content of bioavailable calcium. Some are rich in vitamin A, iron, zinc and essential fats. Measures to improve management and increase culture and consumption of small fish include community-based management of common water bodies; culture of small fish in ponds and rice fields; use of small marine fish for direct human consumption, especially in vulnerable population groups; and improved handling, transportation, processing – especially drying – and market chains to reduce loss and increase accessibility, especially in hard to reach population groups. Recent integrated initiatives such as Scaling Up Nutrition (SUN) Framework and Roadmap: 1,000 Days Global Effort, focusing on the linkages between agriculture and nutrition give good opportunities for promoting improved management, and increased culture and consumption of small fish species.

1. Introduction
In many low-income countries, with water resources, fish and fisheries are an integral part of the livelihoods, nutrition and income of the rural poor. In these population groups, a large proportion of the fish caught, bought and consumed is from capture fisheries, and made up of small fish species. However, as national statistics on fish production and consumption fail to capture data on these small fish species, their importance in diets is neglected (Roos *et al.*, 2006). Very few consumption surveys have reported on fish intake at species level. In Bangladesh, data from some rural surveys show that small freshwater fish species make up a large part of total household fish consumption; fish is a traditional and common food; the frequency of fish intake is high; and the amounts consumed are small. These surveys also show that fish is an irreplaceable animal source food for the rural poor; adding diversity to a diet dominated by one grain staple, rice. In addition, survey data show that the total fish consumption among the rural poor has decreased, as well as the proportion of small fish species of total fish consumption (Thompson *et al.*, 2002). In Bangladesh, small indigenous fish species are characterized as species growing to a maximum of 25 cm or less. In some African countries, for example, Malawi, Kenya, Tanzania and Zambia, the importance of small fish species, for example kapenta (*Limnothrissa* spp.) as a major animal source food in the diets of rural populations, living close to lakes is recognized (Haug *et al.*, 2010). In coastal communities, small marine fish species are also important in the diets of the poor.

2. Factors related to the small size of fish which benefit consumption
There are many factors related to the small size of fish species, which make them especially favourable for inclusion in the diets of the rural poor. In Bangladesh, the diversity of small fish species is large; and a large proportion of the over 267 freshwater and 400 species from the mangrove waters in the Sundarbans is of small size (Islam and Haque, 2004; Rahman, 1989). Capture fisheries continue to be an important source of fish. In the monsoon and post-monsoon periods (June–November), the floodplains are inundated, providing an ideal habitat for the many fish species, and people have access to these for consumption as well as local sale. Much of the small fish is sold in small rural markets, and this is the major source of fish for consumption by the rural population. Small fish are sold in small heaps of mixed species, can be bought in quantities which are affordable, and can be cooked for one meal or for daily consumption, favouring a high frequency of consumption (Roos, 2001). This is important, taking

into consideration that fish is highly perishable and the rural population does not have the possibility to keep foods cold or frozen. In northern Zambia, heaps of around 20 g raw chisense (many small fish species, dominated by *Poecilothrissa moeruensis*) are sold and bought. Fish capture and production are highly seasonal with peak and lean seasons, and processing of fish, especially sun-drying gives the possibility to make good use of small fish species which are plentiful and affordable in the peak season, reduce weight which eases transportation and storage, as well as extend the length of storage time and duration of intake. Traditional products such as dried, smoked, salted and fermented small fish, as well as fish paste and fish sauce are made at household level and bought in small quantities from local markets. Raw and processed small fish are normally cooked as a mixed curry or stew dish, with little oil, vegetables and spices. It is reported that these dishes are well-liked, easy to prepare, add taste and flavour to meals made up of large quantities of one staple, for example rice or maize, as well as contribute to dietary diversity. A dish with small fish and vegetables can be shared more equitably among household members, including women and young children (Roos et al., 2007b). Surveys of perceptions of small fish species in rural Bangladesh show that many are considered beneficial for well-being, nutrition and health, and women ranked small fish as the second most preferred food to buy – after fruits – if they had more income to spend on food (Deb and Haque, 2011; Nielsen *et al.*, 2003; Thilsted and Roos, 1999).

3. Intake and nutritional contribution of small fish species

Some rural surveys have shown the effect of location, seasonality, year and household socio-economic status on fish consumption. In a survey conducted in 1997–98, in an area in northern Bangladesh with rich fisheries resources; the average fish intake in the peak fish production season (October), 82 g raw, edible parts/person/d was more than double that in the lean season (July); and five common small species made up 57 percent of the total intake (Roos *et al.*, 2003). The nutritional contribution of small fish species is high. It is well recognized that fish are a rich source of animal protein, and some marine fish have a high content of total fat and essential fats. Recently, some small freshwater fish species have been reported as being rich sources of fat and essential fats. Trey sloeuk russey (*Paralaubuca typus*) from Cambodia has a high fat content (12 g/100 g dried fish) (Roos *et al.*, 2010). Dried usipe (*Engraulicypris sardella*) from an area around Lake Malawi contains 1 700 mg docosahexaenoic acid (DHA) per 100 g dried fish, comparable to salmon. The DHA concentration in the breast milk of women from this area was found to be about 0.7 percent of fatty acids; about twice the global average (K. Dewey, personal communication, 7 April 2011).

However, the contribution of small fish species as a rich source of vitamins and minerals has not been widely documented and is overlooked. In the above-mentioned study from Bangladesh, small fish contributed 40 percent and 31 percent of the total recommended intakes of vitamin A and calcium, respectively, at household level, in the peak fish production season (Roos *et al.*, 2006). Some common small species, mola (*Amblypharyngodon mola*), chanda (*Parambassis* spp), dhela (*Ostreobrama cotio cotio*) and darkina (*Esomus danricus*) have high content of vitamin A. As most small fish species are eaten whole, with bones, they are also a very rich source of highly bioavailable calcium. Darkina, as well as trey changwa plieng (*Esomus longimanus*) from Cambodia have a high iron and zinc content (Roos *et al.*, 2007a). A traditional daily meal of rice and sour soup made with trey changwa plieng can meet 45 percent of the daily iron requirement of a Cambodian woman. In addition, fish enhances the bioavailability of iron and zinc from the other foods in a meal (Aung-Than-Batu *et al.*, 1976).

4. Measures to increase the availability and consumption of small fish species

With fast-growing populations in low-income countries, changing trends in use of land and water, overfishing, degradation of fish habitats and lack of management of water and fisheries resources, the availability of freshwater fish, especially small species has decreased. In some Asian countries, aquaculture of large, fast-growing fish species has been vigorously promoted in response to declining fish availability. In Bangladesh, pond polyculture of carps, and recently, monoculture of the introduced species, Nile tilapia (*Oreochromis niloticus*) and pangas (*Pangasius sutchi*), mainly for urban markets, have been very successful. The intake of silver carp (*Hypophthalmichthys molitrix*) – a large fish which is not well liked and makes up a large proportion of aquaculture production – has increased among the poor, as total fish intake has decreased. Due to species differences in nutrient content, as well as large fish not eaten whole as small fish – for example, the bones are plate waste – this production technology of large fish does not favour increased fish consumption by the poor or contribution to micronutrient intake (Roos *et al.*, 2007b).

Recognizing the decline in biodiversity of indigenous freshwater fish species in Bangladesh, as well as growing attention to the nutritional importance of small species, some measures have been taken to conserve, manage and culture indigenous fish.

Conservation and management of common fisheries resources and fish migration routes through community-based and community-managed fisheries approaches have proved successful in increasing total fish production many times, the diversity of fish species, as well as the proportion of small fish species captured and consumed by landless and small farming households (Center for Natural Resource Studies, 1996). Similar positive results have been achieved in the Management of Aquatic Ecosystems through Community Husbandry (MACH) projects (1998–2003) which included interventions to restore three major wetlands habitats, ensure sustainable productivity and improve the livelihoods of the poor who depend on these wetlands, through community based co-management (Anonymous, 2003).

Pond polyculture of carps with the vitamin A rich small fish, mola was introduced in Bangladesh in the late 1990s. No significant difference in total fish production was seen between ponds stocked with carps and mola, and those with carps alone. However, the nutritional quality of the total fish production improved considerably in the ponds with mola. In this production system, the eradication of indigenous fish, the majority being small species, by repeated netting, dewatering, and the use of a piscicide, rotenone; pre-stocking of carp fingerlings – based on the rationale that competition exists between native and stocked fish – was stopped. As small fish species breed in ponds, frequent partial harvesting must be practised, and this favours home consumption. In addition to the production of carps, a small mola production of 10 kg/pond/y, in the estimated four million small, seasonal ponds in Bangladesh can meet the annual recommended vitamin A intake of six million children (Roos *et al.*, 2007b). This production technology of carp-small fish pond polyculture has gained wide acceptance by the Government of Bangladesh and development partners, and is also being practised in Sundarbans, West Bengal and Terai, Nepal. Carp production and management of indigenous fish species in beels (floodplain depressions and lakes) have also resulted in large increases in total fish production (over 0.6 tonnes/ha, in 6 months, of which 45 percent were non-stocked fish, mainly small species) (Rahman *et al.*, 2008). Depending on geographical location and season, different culture practices with fish and rice have shown to increase fish diversity, as well as the nutritional quality of the combined rice and fish production (Dewan *et al.*, 2003; Kunda *et al.*, 2009).

A central issue regarding the availability of small fish species for direct human consumption is the vast amounts of small marine fish (about 23.8 million tonnes in 2006) used to produce fish meal and fish oil, primarily for aquaculture (Tacon and Metian, 2009). There is growing concern of the dwindling supplies and population collapse of small marine fish species (Pinsky *et al.*, 2011). More focused advocacy and awareness, as well as development and implementation of policies, regulations and interventions are needed in order to significantly reduce this trend. Fish powder made from small marine fish can be used as an excellent source of essential nutrients in feeding programmes for pregnant and lactating women, young children, school children, the sick and elderly. In the WINFOOD project presently being conducted in Cambodia and Kenya, complementary foods for young children with powdered, nutrient-rich small fish species have been developed, and efficacy studies are being carried out (Roos *et al.*, 2010).

Improving handling and transportation, processing and market chains to reduce the large amounts of fish lost due to spoilage and waste can greatly increase the accessibility of small fish and fish products to the poor and population groups which are hard to reach. Recognizing that improvements in transportation and storage systems for raw fish can be difficult to achieve in low-income countries, much more efforts should be made to improve traditional sun-drying methods. In Mali, a simple, robust mobile fish dryer has been developed which eliminates contamination caused by spreading the fish on soil, and the use of insecticides to keep away flies during sun-drying. In addition, the time needed for drying is short, and the temperature used is controlled and lower than that reached from direct exposure to the sun, resulting in a product of high nutritional and food safety quality (Heilporn *et al.*, 2010).

5. Conclusion

Recent attention to linkages between agriculture, human nutrition and health gives new possibilities to focus on management and culture of small fish species for improved diets. There are initiatives such as the CGIAR Research Programmes; USAID funded Feed the Future; Scaling Up Nutrition (SUN) Framework and Roadmap: 1,000 Days Global Effort; Bill and Melinda Gates Foundation, Grand Challenges Explorations Rounds 7 and 8: Explore Nutrition for Healthy Growth of Infants and Young Children; and CIDA funded Grand Challenges Canada: Saving Brains focus on integrated approaches to improve nutrition. For implementing SUN: 1,000 Days Global Effort, recommendations for the increased availability, accessibility and intake of fish as a rich source of essential fats, crucial for cognitive development have been highlighted.

References

Anonymous (2003). MACH completion report: management of aquatic ecosystems through community husbandry. Volume 3: Fish catch & consumption survey report. Retrieved July 1, 2011 from: http://www.nishorgo.org/nishorgo2/pdf/march_report/Volume%203%20Fish%20Consumption.pdf

Aung-Than-Batu, Thein-Than, Thane-Toe (1976). Iron absorption from Southeast Asian rice-based meals. American Journal of Clinical Nutrition, 29, 219-225.

Center for Natural Resource Studies (CNRS) (1996). Community-based fisheries management and habitat restoration project. Annual report. July 1995-June 1996. Dhaka, Bangladesh: CNRS.

Deb, A. K. & Haque, C. E. (2011).'Every mother is a mini-doctor': ethnomedicinal use of fish, shellfish and some other aquatic animals in Bangladesh. Journal of Ethnopharmacology, 134 (2), 259-267.

Dewan, S., Chowdhury, M. T. H., Mondal, S., Das, B. C. (2003). Monoculture of Amblypharyngodon mola and Osteobrama cotio cotio in rice fields and their polyculture with Barbodes gonionotus and Cyprinus carpio. In Md. A. Wahab, S. H. Thilsted, Md. E. Hoq (Eds.), Small indigenous species of fish in Bangladesh: culture potentials for improved nutrition and livelihood (pp.23-35). Mymensingh, Bangladesh: Bangladesh Agricultural University.

Haug, A., Christophersen, O. A., Kinabo, J., Kaunda, W., Eik, L. O. (2010). Use of dried kapenta and other products based on whole fish for complementing maize-based diets. African Journal of Food, Agriculture, Nutrition and Development, 10 (5) 2478-2500.

Heilporn, C., Benoît, H., Debaste, F., van der Pol, F., Boey, C., Nonclercq, A. (2010). Implementation of a rational drying process for fish conservation. Food Security, 2, 71-80.

Islam, Md. S. & Haque, M. (2004). The mangrove-based coastal and near shore fisheries of Bangladesh: ecology, exploitation and management. Reviews in Fish Biology and Fisheries, 14, 153-180.

Kunda, M., Azim, M. E., Wahab, M. A., Dewan, S., Majid, M. A., Thilsted, S. H. (2009) Effects of including catla and tilapia in a freshwater prawn-mola polyculture in a rotational rice-fish culture systems. Aquaculture Research, 40 (9), 1089-1098.

Nielsen, H., Roos, N., Thilsted, S. H. (2003). The impact of semi-scavenging poultry production on intake of animal foods in women and girls in Bangladesh. Journal of Nutrition, 133, 4027S-4030S.

Pinsky, M., Jensen, O. P., Ricard, D., Palumbi, S. R. (2011). Unexpected patterns of fisheries collapse in the world's oceans. Proceedings of the National Academy of Sciences of the United States of America, 108 (20), 8317-8322.

Rahman, A. K. A. (1989). Freshwater fishes of Bangladesh. Dhaka, Bangladesh: Zoological Society of Bangladesh.

Rahman, M. F., Barman, B. K., Ahmed, M. K., Dewan, S. (2008). Technical issues on management of seasonal floodplains under community-based fish culture in Bangladesh. In Proceedings of the CGIAR Challenge Programme on Water and Food (Vol. II, pp. 258-261). 2nd International Forum on Water and Food, Addis Ababa, Ethiopia.

Roos, N. (2001). Fish consumption and aquaculture in rural Bangladesh: nutritional contribution and production potential of culturing small indigenous fish species (SIS) in pond polyculture with commonly cultured carps. PhD Thesis, The Royal Veterinary and Agricultural University, Denmark.

Roos, N., Islam, M., Thilsted, S. H. (2003). Small fish is an important dietary source of vitamin A and calcium in rural Bangladesh. International Journal of Food Sciences and Nutrition, 54, 329-339.

Roos, N., Nurhasan, M., Bun Thang, Skau, J., Wieringa, F., Kuong Khov, Friis, H., Michaelsen, K. F., Chamnan, C. (2010). WINFOOD Cambodia: Improving child nutrition though improved utilization of local food. Poster presentation. Biodiversity and sustainable diets: united against hunger. Symposium hosted by Bioversity International and FAO, 3rd-5th November 2010, Rome, Italy.

Roos, N., Wahab, M. A., Chamnan, C., Thilsted, S. H. (2006). Fish and health. In C. Hawkes & M. T. Ruel (Eds.), 2020 vision: understanding the links between agriculture and health: Focus 13 (Brief 10 of 16) Washington D. C., U.S.A.: International Food Policy Research Institute (IFPRI).

Roos, N., Wahab, M. A., Chamnan, C., Thilsted, S. H. (2007a). The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. Journal of Nutrition, 137, 1106-1109.

Roos, N., Wahab, M. A., Hossain, M. A. R., Thilsted, S. H. (2007b). Linking human nutrition and fisheries: incorporating micronutrient dense, small indigenous fish species in carp polyculture production in Bangladesh. Food and Nutrition Bulletin, 28 (2) Supplement, S280-S293.

Tacon, A. G. J. & Metian, M. (2009). Fishing for feed or fishing for food: increasing global competition for small pelagic forage fish. Ambio, 38 (6), 294-302.

Thilsted, S. H. & Roos, N. (1999). Policy issues on fisheries and food and nutrition. In M. Ahmed, M., C. Delgado, S. Sverdrup-Jensen, R. A. V. Santos (Eds.), Fisheries policy research in developing countries. Issues, policies and needs. (60, pp.61-69) ICLARM Conference Proceedings.

Thompson, P., Roos, N., Sultana, P., Thilsted, S. H. (2002). Changing significance of inland fisheries for livelihoods and nutrition in Bangladesh. Journal of Crop Production, 6, 249-317.
Also in P. K. Kataki & S. C. Babu (Eds.), Food systems for improved human nutrition: linking agriculture, nutrition and productivity. New York, NY, USA: Howard Press.

TRADITIONAL FOOD SYSTEMS IN ASSURING FOOD SECURITY IN NIGERIA

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Introduction

Traditional food systems refer to the human managed biophysical systems that are involved in the production, distribution and consumption of food in a particular environment. Food systems are a natural locus for improving nutrition security in societies because agriculture is the primary employment sector for the extremely poor and because food consumes a very large share of the expenditures of this group of people. The causal mechanisms underpinning the poverty trap in which the poor, unhealthy and undernourished rural Africans too often find themselves remain only partially understood, but are clearly rooted in the food system that guides their production, exchange, consumption and investment behaviours.

The most basic thing we know is that ill health, malnutrition and extreme poverty are mutually reinforcing states. The links are multidirectional. Low real incomes are the primary cause of chronic and acute hunger, as a vast literature spawned by Sen (1981) emphasizes. Even when food availability is adequate – which is not the case in large portions of SSA today – low incomes impede access to sufficient and appropriate food to maintain a healthy lifestyle. But causality runs the other way as well. The WHO (2002) reports that undernutrition, including micronutrient deficiencies, is the leading risk factor for disease and death worldwide, accounting for over half the disease burden in low-income countries. Undernutrition also impedes cognitive and physical development, thereby depressing educational attainment and adult earnings.

Disease, in turn, impedes the uptake of scarce nutrients, aggravating hunger and micronutrient malnutrition problems and hurting labour productivity and earnings. Indeed, recent research suggests that major health shocks are perhaps the leading cause of collapse into long-term poverty (Gertler and Gruber, 2002; Barrett and Swallow, 2006). And a large literature amply demonstrates the corollary that improved nutrition and health status increase the current and lifetime productivity of individuals, thereby increasing incomes and assets and contributing to poverty reduction (Dasgupta, 1997). Food systems are the natural locus for developing an integrated strategy for addressing hunger, ill health and poverty jointly and thus assuring nutrition security.

Nutrition security is the access to adequate diet by every member of the household. Access to food is tied to production of enough food by the agricultural system, importation of food, income, cooking methods and household food-sharing formula. Each of these factors is multifaceted such that an attempt to individually discuss them will be impossible within the scope of this write-up.

What are these traditional food systems

These involve the methods and types of foods produced within the given community or state or country. In Nigeria the traditional foods available are many and varied depending on climate/agro-ecological zone. Traditional foods are foods produced locally which form part of the food culture inherent in the locality. The local climate enables the cultivation of such crops either for subsistence or for cash or both.

Food plants are traditional in the sense that they are accepted by rural communities by custom, habit and tradition as appropriate and desirable food. People are used to them; they know how to cultivate and prepare them and enjoy the dishes made from them. They are grown for food within the farming systems operating in any particular locality or gathered as wild or semi-wild products. There are two groups of foods: those consumed in the areas where they are grown as traditional dietary staples, for example, cassava, yam, cocoyam, sweet potatoes (*Ipomoea batatas*), plantains (*Musa paradisiaca*) and maize. The second group is made up of those consumed as a component of accompanying relishes

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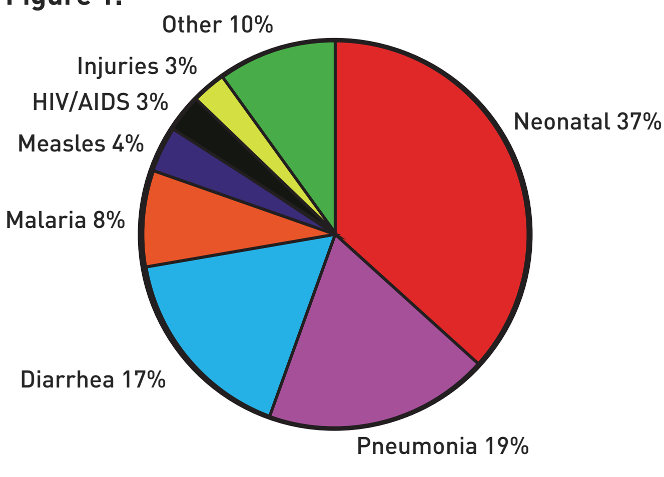
and sauces. These include oilseeds, fruits and vegetables. There is no universally accepted shortlist of such plants. Communities have evolved their own preferences and food habits (Okeke *et al.*, 2008).

Improvement in the food systems have been found to greatly reduce hunger, improve income and reduce malnutrition and the related disease conditions in so many countries.

Child mortality is 88 deaths per 1 000 live births, overall under-five mortality rate is 138 deaths per 1 000 live births and there is a drop in exclusive breastfeeding (EBF) from 17 percent to 13 percent (NDHS, 2008).

Food security is closely linked to nutrition security. In Nigeria malnutrition contributes to unacceptably high maternal, newborn and child mortality rates. A woman's chance of dying from pregnancy and childbirth is 1 in 13. Other data show that infant mortality rate (IMR) is 75 deaths per 1,000 live births. Over 50 percent of the underlying causes of these deaths is undernutrition.

Figure 1.



A few questions naturally arise at this point

1. What is the nature of the Nigerian traditional food system?
2. What are the methods of food production in Nigeria?
3. What are the traditional foods in Nigeria?
4. What are the nutrient compositions of traditional Nigerian foods?
5. Can the traditional food systems and the nutrient compositions assure nutrition security?

The Nigerian traditional food system is characterized by low return on investments, crude and ineffective farm implements, low irrigation, expensive inputs such as fertilizers, improved planting materials, low yielding plants and livestock etc.

Classification of traditional foods

Traditional foods in Nigeria can be classified into the following:

a. Roots and tubers
b. Cereals and legumes
c. Vegetables and fruits
d. Herbs and spices
e. Livestock and game

a. Roots and tubers

Examples of roots and tubers include cassava, yams, coco yams – these are mainly produced and consumed in the humid savannah and rainforest agro-ecological zones. These stretch from the middle belt to the southern part of Nigeria.

b. Cereals and legumes

Examples include maize, sorghum, millet, acha, rice, beni seed (cereals), and cowpeas, pigeon pea, African yam bean, bambara nuts.

Food products from cereals include boiled rice, jollof and rice pudding, e.g. tuwo shinkafa, cornfood, pap, eko/agidi, "maize–rice", African bread fruit jollof, toasted bread fruit seeds, beni seed soup, acha, tuwo masara, boiled or roasted corn. Legume products include boiled beans, mashed beans, rice and beans, jollof beans, moin, akara, gbegiri soup, bean pottage, roasted groundnut, groundnut soup. Products from roots and tubers include the following: pounded yam, amala (yam flour paste), garri, boiled yam, akpu, tapioca, abacha flakes.

A woman and two children peeling cassava and tubers of yam on display for sale

Tubers of yam

Yellow maize

Unshelled groundnuts

Millet

Different types of legumes

c. Fruits and vegetables

Fruits are described as the ripened seeds of plants and the adjoining tissues which house them (Onimawo and Egbekun, 1998). They are commonly used as desserts.

Vegetables are the leafy outgrowth of plants or part of plants that are used in making soups or eaten with the principal part of a meal. In southern Nigeria, leafy vegetables are grouped into:

i cultivated leafy vegetables such as pumpkin, green (spinach), bitter leaf, ewedu, water leaf;
ii semi-wild vegetables which grow wild in the bush but are now protected to grow in the home garden, e.g. utazi, uziza, atama (Ibos) okpai (Edo);
iii wild vegetables – okazi, edikan (Ibibio and Efik).

Many useful fruit trees which are exploited from semi-wild conditions include breadfruit (*Treculia* sp.), African pear (*Dacroydes* sp.), *Irvingia* sp. and *Pentaclethra macrophylla* (oil bean seed), *Dialium* sp., *Parkia vitex* and *Chrysophyllum* sp. Wild and semiwild leaf vegetables of importance include *Pterocarpus* sp., *Pergularia* sp. and *Gnetum* sp.

Several fruits exist in Nigeria. These fruits are distributed across the agro-ecological zones. In the humid savannah several of the fruits include pawpaw (*Carica papaya*), oranges, guava, lime, grapes, African star apple (udara), mangoes, velvet tamarin (*Vitex doniana*), bananas, tangerine, cashew, garden eggs. In the northern part of Nigeria, particularly in the Plateau State axis there are different types of vegetables such as carrots, cabbage, water melon, garden eggs. About 294 species and over 400 varieties of foods were documented in the south-

A bunch of bananas

Mango

Pawpaw

Tomatoes

eastern part of Nigeria alone (Okeke *et al.*, 2008). Twenty-one species of starchy roots and tubers, 20 legumes, 21 nuts/seeds, 116 vegetables, 12 mushrooms and 36 fruits have been documented in southern Nigeria. Cereals, starchy roots and tubers are important food groups for the majority of Nigerians. The foreign rice syndrome has in the recent past overtaken many households, especially in the urban areas.

Generally, plant foods are available all year round but are more abundant during the harvest season. The most commonly consumed legume in Nigeria is the cowpea (*Vigna unguiculata*). Local varieties of cowpea and other species of legumes are also available but not produced in very large quantities including bambara nut, African yam bean, groundnut. Mushrooms are also consumed though in relatively small quantities. Fruits are not main parts of the diet but are eaten outside regular meals. Two types of oil (red palm oil and vegetable oil – mainly ground nut oil) are commonly used. A total of 21 condiments and spices were identified. Some of these condiments are soup thickeners and are high in dietary fibre.

Animal foods were about 27 species for meat/poultry/eggs, 12 species of fish and 3 species of insect/larvae were documented (Okeke *et al.*, 2008). The most popular game meats are grasscutter, rabbit and antelope. Milk and milk products are not common food items except in the northern part of Nigeria but rare in the usual diets of most households in the southern part of Nigeria. In most communities, foods are eaten not only for their nutritional values but also for their medicinal and sociocultural significance.

Green amaranthus

Okra

Table 1. Some Nigerian traditional foods.

	Scientific name Fruits	English/ common name	Local name	Preparation
1	Abelmoschus esculenta	Lady's finger	okwulu npiene	Used for soups
2	Anacardium occidentalis	Cashew	mkpuru cashew	Roasted and eaten as a snack
3	Anonas comosus	Pineapple	Akwuolu	Fruit eaten when ripe
4	Anonas muricarta	Soursop		Fruit eaten when ripe
5	Artocarpus communis	Breadfruit	ukwa bekee	-
6	Azadirachta indica	Neem	Dogoyaro	Used for malaria
7	Canarium schweinfurthii	Pear	ube okpoko	Soften in hot water and pulp eaten
8	Carica papaya	Pawpaw	okwuru ezi	Fruit eaten when ripe
9	Chrysophyllum albiduim	Bush apple (African star apple)	udala nkiti	Fruit eaten when ripe
10	Citrus aurantifolia	Orange	Oromankiti	-
11	Citrus aurantium	Orange	Oroma	Fruit eaten when ripe
12	Cocos nucifera	Coconut	Akuoyibe	Eaten raw with corn/maize
13	Cola spp.	`kola	oji ogodo	Chewed raw, medicinal
14	Curcurbita pepo (2 var.)	Pumpkin	anyu, ugboguru	Used to cook yam or cocoyam. Soften on cooling, boiled and eaten as snack
15	Curcurbita pepo (1 var.)	Pumpkin	nkpuru anyu	Boiled, milled and used for soup
16	Dacryodes edulis (2 var.)	Pear	ube Igbo	Soften in boiled water or roasted and used to eat maize,corn or alone
17	Dennettia tripetala	Pepper fruit	Mmimi	Hot pepper eaten alone or with garden eggs
18	Dialium guineense	Velvet tamarind	Icheku	Eaten raw
19	Elaeis guineensis	Palm fruit	Aku	Major source of cooking oil
20	Garcinia kola	Bitter cola	aki ilu	-
21	Grewia spp.	Jute plant	Ayauma	-
22	Husolandia opprosita	Mint	Aluluisinmo	Used for upset stomach
23	Icacemia spp.	-	Urumbia	Eaten as a fruit
24	Irvingia spp.	Bush mango	Ugiri	Fruit eaten when ripe
25	Landolphia owariensis	Rubber plant	utu npiwa	Fruit eaten when ripe
26	Landolphia spp. (4 var.)	Rubber plant	akwari, ubune utu mmaeso, utu mmaenyi,	Fruit eaten when ripe
27	Lycopersicum esculentum (4 var)	Tomatoes	tomatoes	Used for stews and other preparations
28	Magnifera indica (4 var.)	Mabgo	mangoro	Fruit eaten when ripe
29	Myrianthus arboreus	Ujuju fruit	ujuju	Fruit eaten when ripe
30	Pachystela breviceps	Monkey apple	udala nwaenwe	F ruit eaten when ripe
31	Persia Americana	Avocado pear	ube oyibo	English pear is ripened and eaten alone
32	Piper umbellate	Sand pepper	njanja	Dry leaves used for soup during the dry season
33	Psidium guajava	Guava	gova	Eaten when ripe
34	Senna occidentalis	Nigero plant	sigbunmuo	Used for cooking yam pottage
35	Solanum macrocarpum	Garden egg fruit	anyara	A fruit eaten with peanut butter or alone
36	Sterculia spp.	Kola (wild) wa ebunne	nkpuruamun	Wild fruit
37	Uraria chamae	-	okpaokuku	Used for soup, tuber used for insect bite
38		-	utabe efi	Wild fruit

Okeke *et al.* (2008), Onimawo and Egbekun (1988).

Nutrient content of some Nigerian traditional foods

Every community in Nigeria has its own food preferences and over the years has developed the taste for such foods. The communities also have their peculiar ways of preparing their traditional foods. These cultural practices contribute to the nutrient content and nutrient retention in traditional foods. Nutrient content of some of these Nigerian foods are shown in Tables 2–8 below.

Table 2. Chemical composition of some tropical roots and tubers (100 g).

Commodity	Dry matter (g)	Crude protein (g)	Crude fat (g)	Total ash (g)	Energy (kcal)	Ascorbic acid (mg)	Calcium (mg)	Phosphorus (mg)	Iron (mg)
Cassava (Manihot utilissima)	31.94	2.71	0.53	2.66	390.0	35.0	10.0	35.0	0.50
Yam (Dioscorea rotundata)	26.17	5.87	0.46	4.30	385.9	17.0	18.9	40.7	0.48
Cocoyam (Taro) (colocasia esculenta)	26.52	8.66	0.71	4.83	376.4	14.0	24.0	53.6	0.72
Cocoyam 2 (Tannia) (Xanthosoma Sagittifolium)	24.89	7.85	0.70	5.22	382.6	10.0	6.0	360.0	0.70
Sweet Potato (Ipomoea batatas)	28.08	5.36	0.33	3.15	391.0	26.2	16.6	31.0	0.83

FAO (1968); Onimawo and Egbekun (1988).

Table 3. Nutrient composition of selected Nigerian traditional foods (per 100 g fresh edible portion).

Food	Moisture	Energy		Protein	Fat	CHO	Fibre	Ash	Vit A (RE)	Thiamin	Riboflavin	Niacin	Folate	Vit C	Calcium	Phosphorus	Iron	Zinc
	g	kcal	kj	g	g	g	g	g	µg	mg	mg	mg	µg	mg	mg	mg	mg	mg
Legumes nuts and seeds																		
Black pepper seed	10.5	324	1 354	3.4	0.2	77.1	4.2	4.6	38.6	0.08	2.3	1.0	3	14.4	254.6	533.2	5.7	3.7
Castor oil seed	39.7	337	1 409	27.4	18.9	14.3	0.3	1.2	54.1	0.14	1.83	1.7	5	25	517.5	450.1	15.3	4.2
Ehulu seed	15.6	321	1 342	3.8	0.2	76.0	1.3	3.1	-	-	-	-	-	-	55.8	549	13.3	2.8
Olima seed	29.2	272	1 137	14.7	0.1	53.1	1.1	1.8	-	-	-	-	-	-	5.4	21.6	12.0	1.8
Pumpkin seed	60.3	121	506	4.8	2.6	19.6	2.1	0.6	29.9	0.37	1.94	1.7	12	1.6	170.5	626.1	3.7	1.4
Seeded herb	56.7	140	585	3.9	0.1	30.8	4.4	4.1	44	0.24	0	3.8	7	4.7	166.8	125.3	3.4	2.4
Uda seed	42.7	247	1 032	3.6	12.4	30.2	6.8	4.3	53.8	0.27	0.34	0.9	10	1.8	-	-	-	-
Vegetable and mushroom																		
Black pepper leaf	67.6	114	477	16.9	1.3	8.7	3.1	2.4	19.4	0.14	0.91	0.7	5	11.7	245.8	13.7	6.4	1.2
Bitter leaf	62.1	154	644	14.6	2.1	19.2	0.4	1.6	31.2	0.13	0.56	0.6	4	8.6	278.3	228.4	3.4	2.2
Cam wood	56.3	144	602	3.5	0.8	30.8	4.8	3.8	29.9	0.37	1.94	1.7	12	1.6	5.3	126.2	9.0	0.9
Ero awaga	67.4	130	543	4.6	1.6	24.2	1.6	0.6	4.1	0.22	0.42	4.5	7	2.3	2.5	240.9	11.2	1.7
Water leaf (wild)	56.7	163	681	22.7	0.1	17.9	1.2	1.4	31.2	0.39	0.28	2.0	13	38.4	114.4	152.9	1.6	114
Water leaf	70.2	74	309	2.4	0.8	14.2	1.0	1.8	-	-	-	-	-	-	89	128.2	1.6	114
Uncommon vegetables																		
Agbolukwu	71.1	107	447	7.9	0.4	18.0	1.7	0.9	18.9	0.28	0.36	3.0	0	4.48	529.0	188	2.0	1.3
Agili ezi	57.9	160	669	6.4	0.3	33.0	0.7	1.6	-	-	-	-	-	-	4.1	15.7	5.4	1.1
Alice mose	65.7	121	506	14.8	0.7	13.9	2.1	2.9	-	-	-	-	-	-	380.9	127.8	11.1	1.6
Aluluisi	36.0	319	1333	4.6	1.2	72.4	1.6	3.4	55.5	0.09	0.93	1.2	3.0	18.0	657.6	338.3	9.5	3.3
Anya-azu	66.4	131	548	12.8	1.3	17.1	0.6	1.8	25.7	0.18	1.1	1.5	6	22.9	166.2	134.6	14.6	1.0
Awolowo weed	47.3	192	803	9.6	0.4	37.4	2.1	3.2	69.5	0.17	0.52	2.4	6	30.8	582.1	326.2	5.8	2.5
Azei	60.8	117	489	4.2	0.4	24.1	6.3	4.2	6.9	0.18	0.36	1.1	6	2.9	43.4	85.0	11.9	1.0
Bush marigold	52.9	181	757	6.8	0.6	37.0	0.9	1.8	-	-	-	-	-	-	473.4	235.6	5.4	2.4
Flame tree	44.0	212	886	8.6	0.3	43.7	0.8	2.6	28.3	1.3	0.54	2.0	44	31.5	76.1	33.8	5.4	2.4
Hog weed	65.9	121	506	8.6	0.2	21.3	1.6	2.4	19.4	0.69	0.86	1.1	23	16.4	65.7	233.8	2.1	1.8
Ifulu nkpisi	46.0	192	803	6.8	0.2	40.7	2.1	4.2	69.5	0.32	0.54	3.7	11	54.4	260.4	131.5	9.4	1.1
Illenagbelede	32.9	210	878	16.4	1.4	32.9	4.6	1.4	32.7	0.36	0.94	1.2	12	16.1	367.4	405.2	9.9	3.3

Table 3 contd.

Nutrient composition of selected Nigerian traditional foods (per 100 g fresh edible portion).

Food	Moisture	Energy		Protein	Fat	CHO	Fibre	Ash	Vit A (RE)	Thia min	Ribofl avin	Niacin	Folate	Vit C	Calcium	Phos phorus	Iron	Zinc
	g	kcal	kj	g	g	g	g	g	µg	mg	mg	mg	µg	mg	mg	mg	mg	mg
Uncommon vegetables (continued)																		
Ikpo kpo	61.6	130	543	2.8	0.4	28.7	2.8	3.7	28.3	0.29	0.43	2.6	1	3.6	263.3	84.0	2.7	2.3
Inine	77.8	109	456	15.4	1.2	9.1	1.5	1.2	64.5	0.15	0.04	13	20	1.2	91.1	137.7	2.0	0.8
Isii osisii	59.3	135	564	3.4	0.9	28.3	4.3	3.8	33.5	0.22	0.13	0.8	7	1.7	32.7	252.8	1.9	0.8
Isi-udele	44.6	211	882	4.8	0.2	47.6	2.1	1.3	4.1	0.22	0.42	4.5	7	2.3	330.9	267.1	10.3	1.8
Lemon grass	47.7	204	853	4.3	0.4	45.8	0.4	1.4	18.2	0.21	0.9	1.2	7	16.1	118.5	154.1	2.7	2.7
Local onion	56.4	142	594	3.8	0.6	30.4	5.2	3.6	41.8	0.57	0.3	2.0	20	2.9	56.9	145.6	6.5	1.2
Mgbidi mgbi	69.7	113	472	2.9	0.1	25.2	1.2	0.9	-	-	-	-	-	-	584	127.3	2.3	3.7
Mint	56.7	147	614	7.3	0.7	27.8	3.9	3.6	-	-	-	-	-	-	488.7	18.8	1.0	1.5
Nghotoncha	49.9	166	694	4.7	0.8	35.1	3.6	5.9	-	-	-	-	-	-	471.6	171.6	7.3	1.2
Nigero plant	56.7	146	610	8.9	0.5	26.4	3.9	3.6	-	-	-	-	-	-	42.7	143.5	5.0	0.8
Obi ogbene	69.5	106	443	4.8	1.2	18.9	1.0	4.6	44.0	0.28	1.10	2.0	9	30.3	326.5	122.0	3.2	1.4
Obu aka enwe	38.4	230	961	6.9	0.3	50.0	1.6	2.6	18.9	0.28	0.36	3.0	0	4.48	42.3	431.1	4.9	1.8
Ogbunkwu	18.6	249	1041	2.1	0.1	60.0	12.3	6.9	0.0	0.12	0.0	1.0	0	0.00	110.6	198.1	3.5	2.0
Ogume okpe	41.2	230	961	6.8	0.8	49.0	1.1	2.1	20.5	0.35	1.7	3.8	16	58.0	162.3	332.9	7.7	2.7
Onunu gaover	35.4	248	1037	3.3	0.1	58.5	0.9	1.8	6.8	0.42	0.32	1.6	0	10.6	152.4	389.8	8.6	3.1
Onunu iluoygbo	69.3	102	426	2.4	0.6	21.8	1.4	4.5	30.9	0.62	0.11	1.6	0	3.6	117.5	88.2	2.4	1.7
Otulu ogwai	42.5	206	861	6.9	0.4	43.7	3.1	3.4	35.9	1.62	0.58	1.8	0	22.8	198.4	417.1	5.75	2.6
Pumpkin	69.0	125	523	22.8	2.8	2.2	1.8	1.4	-	-	-	-	7	-	147.4	130.2	0.3	0.8
Senna plant	58.4	159	665	6.8	0.6	31.5	0.9	1.8	51.7	0.45	1.4	1.3	15	18.6	314.3	307.3	6.2	1.5
Ugbfoncha	57.2	140	858	8.6	1.1	23.8	2.4	6.9	30.4	0.24	0.6	1.4	0	26.4	295.5	231.5	4.5	1.9
Ujuju	58.1	148	619	8.3	1.2	25.9	2.1	4.4	16.0	0.23	0.87	1.3	8	18.4	3.3	176.0	1.6	0.8
Utazi	56.7	172	719	18.0	4.8	14.2	3.6	2.7	20.4	0.3	0.82	0.2	0.0	0.3	258.6	204.9	8.1	1.4
Meat																		
Canda (skin)	38.4	320	1338	28.3	16.8	13.9	0.0	2.6	30.9	0.62	0.11	1.6	0	3.6	8.15	160.0	5.4	2.0
Snail	65.7	126	527	10.6	1.2	18.2	0.0	4.3	-	-	-	-	-	-	204.8	161.6	5.8	1.0

Table 4. Key micronutrient-rich traditional foods by food groups/species.

Food group/species	Local name	Scientific name	Major micronutrient(s)
Cereals			
Yellow maize	Oka	Zea mays	β-carotene
Starchy roots/tubers			
Sweet potatoes	Ji nwannu	Ipomaea batatas	Iron, β-carotene
Three leaf yam	Ona	Dioscorea dumentorum	Iodine,
Yellow yam	Ji Oku/Okwu	Dioscorea cayenensis	β-carotene, iodine, iron
Starchy fruits			
Banana	Unele, Ogede	Musa sapientum	Zinc, folate, iron, β-carotene
Plantain	Nba/jiono Obughunu	Musa paradisiacal	Zinc, folate, iron
African bread fruit	Ukwa	Treculia Africana	Iron, zinc
Legumes/nuts and seeds	All legumes/nuts	All legumes/nuts	Iron, zinc, copper
Cashew	Mkpuru/ Mkpulu cashew	Anacardium occidentalis	Iron, zinc
All fruits	Mkpulu osisi	All fruits	Iron, zinc, carotenoids, copper, selenium, vitamin C, vitamin E
Palm fruit	Aku	Elaeis guineensis	β-carotene
All vegetables	Akwukwo nni	All vegetables	Iron, zinc, carotenes
Mushroom	Ero/elo	Not yet properly identified	Iron, copper, zinc
All animal foods	See Table 3	See Table 3	Iron, zinc, vitamin A

Adapted from Okeke *et al.* (2008); Oguntona and Akinyele (1995).

Table 5. Recommended curing and storage conditions for roots and tubers.

Commodity	Temperature °C	Relative humidity %				
	Curing	Storage	Duration of curing (days)	Curing	Storage	Duration of storage (weeks)
Cassava	25–40	32.38	4–9	80–85	58–90	8
Yam	25–40	13–16	5–10	55–62	70	21–28
Cocoyam (Taro)	11–13	30–35	18–21	85–90	70–80	4
Cocoyam (Tannia)	11–13	30–35	18–21	85–90	70–80	4
Sweet Potato	30–32	13–16	13–20	90	85–90	21–28

Okaka (1997).

Table 6. Some fruits and vegetables.

Fruits	Vegetables
Avocado	Beans
Banana	Peas
Breadfruit	Carrot
Pineapple	Cucumber
Mango	Eggplant
Guava	Onions
Pawpaw	Garlic
Oranges	Pepper
Grapefruit	Melon
Lemon fruit	Tomatoes
Tangerine	Pumpkin leaf
Plantain	Lettuce
Cashew apple	Spinach
Passion fruit	Cabbage
Pears	Amaranths
Sour sop	Bitter leaf

Table 7. Typical composition of some fruits and vegetables per 100 g edible portion.

Commodity	Water(%)	Energy (cal)	Protein (%)	Fat(%)	Carbo hydrate (%)	Ascorbic acid (%)	Calcium (mg)	Phospho rus(mg)	Vit. A (I.U.)
Fruits									
Banana	75	86	1.1	0.2	24	10	8	26	190
Pineapple	85	65	0.4	0.4	15	110	20	11	30
Mango	83	63	0.6	0.1	15	30	10	10	180
Guava	80	58	1.0	0.4	13	200	15	33	200
Orange	86	49	1.0	0.2	12	50	41	20	200
Lemon	85	58	1.0	0.9	11	43	40	22	
Cashew apple	85		0.7		13	250	10		150
Pawpaw ripe	81	40	0.5	0.6	10	110	16	8	2 200
Vegetables									
Onions	89	38	1.5	0.1	9	10	27	56	40
Carrot	88	42	1.1	0.2	10	51	37	36	11 000
Spinach	91	26	3.2	0.3	5	51	93	51	8 100
Cabbage	92	24	1.3	0.2	4	47	49	29	130
Pepper	92	22	1.2	0.2	4	125	9	22	420
Tomato	93	22	1.1	0.2	5	30	13	27	190

Table 8. Nutrient composition of some protein foods per 100 g.

Food	Moisture (g)	Protein (g)	Fat (g)	Ash (g)	Dietary fibre (g)	CHO (g)	Calcium (mg)	Iron (mg)
Legumes								
Cowpea (black eye pea)	0	27	2.0	4.1	17.1	50	83	7.4
Pigeon pea	0	22	1.8	3.9	23.8	48	110	5.0
African yam bean	0	22	2.1	3.1	19.1	54	46	4.7
Bambara nut	10	19	6.0	3.4		61	62	12.0
Lima bean	12.7	21	1.4	3.4		61	11	4.9
Soya bean	9.5	34	18.0	5.0		34	183	6.1
Groundnut (dried)	6.5	23	45	2.5		23	49	3.8
Groundnut (roasted)	1.8	23	51	2.4		22	42	
Groundnut (boiled)	44.6	17	8.5	4.0		26	45	5.1
Oil bean seed	8	26	40			20	190	16.0
Pumpkin	5	28	52	3.6		8	53	7.3
Animal foods (meat)								
Beef (moderate fat)	63	18	17.7	1.0			11	3.6
Egg	79	11.8	9.6	1.0		1	45	2.6
Goat Meat (moderate fat)	68	18.0	11.0	1.1			11	2.3
Intestine (cattle)	76	14.5	9.3	0.8		1	10	3.4
Liver (cattle)	70	19.0	4.7	1.3		5	8	10.0
Pork (moderate fat)	46	12.4	40.5	1.0			11	1.8
Chicken	72	20.5	6.5	1.0			10	1.1
Fish and other sea foods								
Crayfish	26	69.5	4.5	13.6			660	155
Mackerel (raw)	64	19.0	16.3				24	1.0
Smoked fish (whole)	5	70.4	10.2	14.2			1 696	25
Crab (meat cooked)	12	31.2	77.0	39.5		10	1 280	
Periwinkle (dried)	14	55	1.4	11.8			733	38.8
Prawn (dried)	16	70.8	6.0	2.5		4	1 740	8.0
Stockfish (raw)	70	21.8	5.4	3.0			1 696	25
Snail	78	12.0	2.0			4	1 500	8.0

Okeke *et al.* (2008); Onimawo (1995); Oguntona and Akinyele (1995).

Contribution of traditional foods to assuring nutrition security

The detailed work carried out by Okeke *et al.* (2008) showed that traditional Nigerian foods fed to children 3–5 years supplied adequate energy (101.24%), protein (149.8%), iron (228.43%), vitamin A (307.9%), thiamin (275.71%), niacin (141.59%) and ascorbic acid (440.05%), which were higher than FAO/WHO requirement intakes. Their intake was adequate for calcium (88.5%) and riboflavin (81.0%) only. Traditional foods contributed over 90% of the energy, protein, thiamin, niacin and ascorbic acid and over 70% of vitamin A and iron intakes of these children.

Among the traditional foods, cereals made the most significant contribution to energy (31.1%) and niacin (39.9%). Legumes made the highest contribution to protein (49.1%). The calcium intake came mainly from vegetables (16.8%) and legumes (16.0%). About 26.5% of the iron came from cereals. This was followed by legumes (26.3%). Only 6.8% of the vitamin A came from vegetables. The rest (71.8%) came from red palm oil. Thiamin and riboflavin came mainly from nuts and seeds (33.9% and 29.9%). The bulk of the ascorbic acid came from starchy roots and tubers (58.1%).

Studies involving school age children 6–12yr (Onimawo *et al.,* 2008) indicated low protein and micronutreints intake particularly iron and zinc. However when meals were prepared from traditionally available foods with appropriate combinations for children 3–5yr, the results showed adequate intake of energy, protein and most of the micronutrients in some cases.

The results from these studies carried out in the southern geopolitical zone in Nigeria show clearly that when properly prepared and combined, Nigerian traditional foods can assure nutrition security even in all segments of the society including the under-fives and school age children.

Frequency of fruits taken

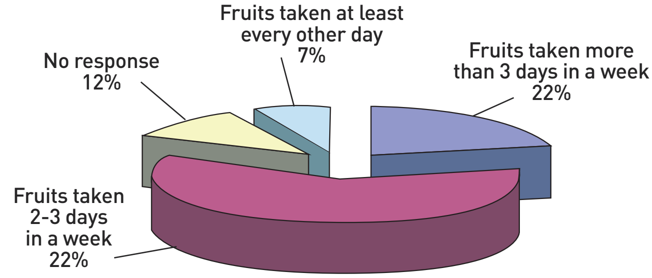


Figure 2. Vegetable consumption pattern of school age children prior to nutrition education.

Frequency of vegetables taken

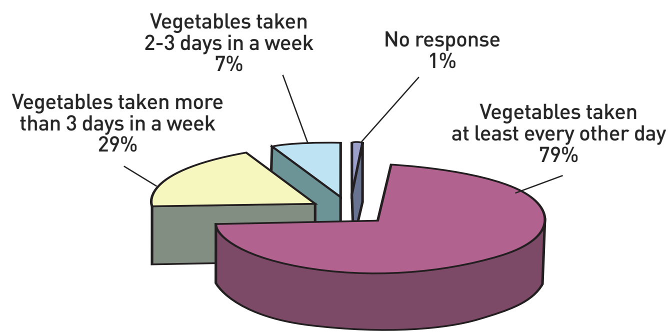


Figure 3.
Improvement in vegetable consumption pattern of school age children after nutrition education.

Following nutrition education, school age children gradually increased vegetable intakes leading to improvement in micronutrient intake of the children. This study further proved that Nigerian traditional foods can support nutrition security if nutrition education is properly carried out.

Summary of the findings on Nigerian traditional foods

Several other studies indicated the following:

- Traditional foods are rich in all the required nutrients.
- Poor combination of the various foods is the bane of adequate nutrient intake.
- Poor processing and culinary methods contribute significantly to nutrient losses.
- Underexploitation of traditional foods undermine their rich nutritional value.
- Lack of nutrition education contributes to the inappropriate uses of traditional foods.

- Low consumption levels of traditional fresh fruits and vegetables contribute significantly to micronutrient deficiency.
- Wrong choice of food and age-long food/dietary habits affected adequate nutrient intake.

There are community variations in the contribution of specific food groups.

- In the southern states in Nigeria, starchy roots and tubers, legumes, nuts and seeds made substantial contributions to energy intake.
- In northern Nigeria, legumes and cereals significantly contribute to the intake of energy.

Conclusion

- Malnutrition characterized by undernutrition is prevalent in Nigeria.
- Undernutrition can be reduced significantly when the traditional Nigerian food system is improved using a combination of strategies including nutrition education.
- One of the main areas that need attention if our traditional food system will assure food security is encouragement of vegetable and fruit consumption. Figures 2 and 3 above show that vegetable and fruit consumption improved significantly after nutrition education of the school children.
- Poverty causes and aggravates malnutrition.
- Need to draw attention to traditional foods that are almost forgotten in preference to westernized diets that invaded our food system.

References

Barrett C B and Brent M. Swallow (2006) Fractal poverty traps. World Development.Vol.34 (1), 1-15

Dasgupta (1997). Nutritional Status, capacity work and poverty traps. Journal of Econometrics.Vol. 77 (1), 5-37

Ene-Obong, H.N. and E. Carnovale, (1992). Nigerian Soup Condiments: Traditional Processing and Potential as Dietary Fibre Sources. Food Chem., 43:29-34.

FAO, 1968. Food Composition Table for Use in Africa. Food and Agricultural Organization, Rome.

Gertler P and Gruber J (2002) in : Paul Gertler , David I. Levine and Enrico Moretti (2005). Do microfinance programs help families insure consumption against illness? John Wiley and Sons.

NDHS (2008). Nigeria Demographic and Health Survey.2008. National Population Commission Federal Republic of Nigeria.

Oguntona, E.B. and I.O. Akinyele, (1995). (Eds.) Nutrient Composition of Commonly Eaten Foods in Nigeria -Raw, Processed and Prepared. Food Basket Foundation Publication Series, Ibadan.

Okaka J C (1997) Cereals and legumes: Storage and processing technology - Data and Microsystems Publishers, Nigeria.

Okeke E.C H.N. Eneobong1, A.O. Uzuegbunam1 and A.O. Ozioko1 and H. Kuhnlein (2008). Igbo Traditional Food System: Documentation, Uses and Research Needs Pakistan Journal of Nutrition 7 (2): 365-376.

Onimawo I A and Egbekun M. K (1988). Comprehensive Food and Nutrition. Ambik Publishers, Benin-City.

Onimawo I A (1995). Seasonal variations in energy intake, expenditure and body composition of students in a Nigeria College of Agriculture – Ph.D. Thesis, university of Ibadan..

Onimawo I A, Asumugha V U, Chukwudi N K, Echendu C A, Nkwoala C, Nzeagwu O C, Okudu H and Anyika J U(2008). Body composition and nutrient intake of children suffering from worm infestation and malaria parasites. Nig. J. Nutr. Sci. Vol.29 (1): 111-117, 2008.

Sen A (1981). On ethics and economics. Blackwell publishing. 350 Main Street, Malden, MA, USA.

WHO (2002). World Health Organization: United Nations. Geneva.

EDIBLE INSECTS IN EASTERN AND SOUTHERN AFRICA: CHALLENGES AND OPPORTUNITIES

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Abstract
Insects have for a long time been known only as pests and pollinators, recent studies show they actually offer more ecological, economic and social benefits to man. On the contrary, entomophagy, the eating of insects has been part of African indigenous diets for as long as the African race has existed. Therefore, edible insects are culturally accepted in many African societies as food. They are a good source of proteins, minerals and essential fats. Edible insects are not used to cope with food scarcity, but are rather an integral part of cultural diets planned for throughout the year. As entomophagy gains popularity in the western world; it is important to closely look at the practice. The potential of insects as food remains poorly understood and taped in Africa with some insects threatened with extinction from unsustainable harvesting, ecosystems destruction and effects of climate change. Insects are one group of foods from the wild that would ensure dietary diversity among many poor people and communities. Incorporating biodiversity in nutrition will go a long way to ensuring food security and sustainable development. This paper explores the challenges and opportunities for wider use of edible insects in traditional diets of the people of eastern and southern Africa.

1. Introduction

Edible insects continue to play a great and significant role in nourishing Africa's indigenous communities. The practice of entomophagy is an age-old one in many African cultures, with many communities paying attention to this aspect in their indigenous knowledge. However, little attention has been paid to this aspect of traditional African diets in western literature until recently. In the past western literature played a great role in labelling them pests creating an apparent contradiction on whether to conserve them for dietary purposes or destroy them as pests.

Studies in entomophagy indicate that consumption of insects is gaining ground not only in Africa but in many parts of western societies (Ayeiko *et al.*, 2010). It has now been realized that entomophagy can make significant contributions to diets as an alternative protein source and to insect conservation through sustainable harvesting in conjunction with appropriate habitat management hence reducing adverse environmental impacts of livestock production (Yen, 2008). The world today is confronted with a larger problem; supplying adequate nutrients in a sustainable way to its growing population as well as protecting the environment. As the world's population continues to grow, great pressure is exerted on land; some edible insects are feared to become endangered or extinct.

According to FAO, more than one billion of the world's population was hungry in 2010, the highest ever registered since 1970. Two hundred and sixty-five million of the world's hungry lived in sub-Saharan Africa and the numbers were likely to increase. Sub-Saharan Africa however, also has the largest prevalence of undernourishment (32%) in the world relative to its population size. Such numbers are unacceptable given that Africa is rich in natural resources among which are forests that contribute about 40% of the world's natural resources and 80% of resources for the world's poor (FAO, 2010), among these resources are highly nutritious foods.

There is a current increase in demand for food production as a result of Africa's rapidly growing population; hence Africa is marred with constant food shortages alongside poverty, these two factors aggravate the nutrition status of many poor families and communities. With the realization of pending food shortage particularly in developing countries, the consumption of edible insects is sure to increase (Meyer-Rochow *et al.*, 2007). Agriculturalists and nutritionists the world over are calling for diversification of diets. Dietary diversification is a priority for improving nutrition and health of the rural and urban poor. Entomophagy contributes to dietary diversification to household diets.

Entomophagy is well accepted in Africa and is a major component in many traditional cultures. As the world becomes a global village, entomophagy is faced with several challenges like land degradation, climate change, globalization and commercialization of agriculture. This paper explores the challenges and opportunities for wider use of edible insects in traditional diets of the people of eastern and southern Africa.

1.1 Edible insects of eastern and southern Africa

Insects possess enormous biodiversity and form great biomass in nature. Insects have played an important role in the history of human nutrition in Africa, Asia and Latin America (Bodenheimer, 1951). They also offer ecological benefits (in pollination, biomass recycling), economic (apiculture, sericulture) and social benefits (in medicine, human and animal nutrition religion, art and handicrafts) (Jharna Chakravorty, 2009). Detailed information regarding the diversity, mode of consumption and economic values of the edible insects in many tropical and subtropical regions of the world is compiled by De Foliart (2002). In eastern and southern Africa, insects are not only pests like it is thought in many parts of the world, they are food items too. In places where animal protein sources are rare or expensive, insects have filled the gap as a major source of protein and animal fat. Insects have been used as livestock feed, human feed and medicine in many African cultures. Huis (2003) reported that there are approximately 250 known edible insect species in sub-Saharan Africa that are high in nutritive value. Preference for which species are utilized depends on their taste, nutritional value, and ethnic customs, preferences or prohibitions. Common edible insect orders in eastern and southern Africa include; Lepidoptera (moths and butterflies), Hymenoptera (bees), Isoptera (termites, queen and reproductives), Coleoptera (beetles), Hemiptera (true bugs), Orthoptera (locusts and grasshoppers), and Odonata (dragon fly). Insects are eaten at different stages of their life cycles; eaten as either larvae or nymphs or adults depending on the insect of interest.

Studies show that arthropods of class insecta are rich in protein especially in the dry form in which they are frequently stored or sold in village markets of developing countries. Some insects are high in fat, and hence energy and many are rich sources of minerals and vitamins (Deforliart, 1995). Illgner and Nel (2000), argue that the importance of entomophagy in Africa is more due to "necessity than choice", because of the climate and small-scale nature of animal husbandry which reduces the amount of meat consumed; the diets have been broadened to include insects. Though, worth noting is, entomophagy is not a coping strategy in the times of crisis as was earlier thought (Bodenheimer, 1951), but rather an integral part of cultural diets in many societies depending on seasonal availability. Entomophagy has been practised for as long as man has lived on the African continent and for that it is incorporated in the indigenous knowledge systems of societies that practise entomophagy. There is a wide base of knowledge that remains undocumented in communities on culinary practices, special traditional harvesting technologies and conservation methods for different and various species of edible insects.

Insect collection and gathering practices are vestiges of the gathering trait seen in our forefathers and therefore it is common to find that many edible insects are collected in the wild. Major gathering spots are woodlands, grasslands and forests. Insects form part of the biodiversity in these ecosystems. It is on this premise, the role of non-wood forest products in food security and development should not be underestimated. Non-wood food products are important in the provision of important community needs that are known to improve rural livelihoods, household food security and nutrition. They help generate additional employment and income, offer opportunities for processing enterprises and more so support biodiversity conservation. Studies show that African diets though lacking in meat proteins, natives still remain healthy and fit. This observation is attributed to edible insects filling in the gaps. Attaining such benefits however comes with various challenges.

2. Challenges

2.1 Climate change

Climate change affects ecosystems and their components with its effects aggravated by unchecked human activities. There is increasing evidence that the earth's climate is undergoing change largely due to human activities. It is estimated that global climate change will have a profound impact on all ecosystems and hence biodiversity (Ayeiko *et al.*, 2010). It is also feared that climate change will lead to loss of biodiversity in many places around the world. The importance of biodiversity in food security, nutrition and sustainable livelihoods cannot be neglected. According to FAO (2010), biodiversity contributes directly to food security, nutrition and human well-being by providing a variety of plant and animal foods from domesticated and wild sources. Environmental integrity is therefore critical for maintaining and building positive options for human well-being.

Insects are an integral part of all ecosystems and will therefore not be spared by the change in a number of ways not yet determined by scientists. Studies point out that insect populations are likely to increase with changing climate (Saunders, 2008). Increased temperature and moisture that are products of climate change are known to affect insect populations. High temperatures stimulate high fecundity in female insects and hence large numbers of individuals at emergency (Rattle, 1985). Ayeiko *et al*. (2010) reported large quantity harvests of termites on the shores of Lake Victoria in western Kenya. They also noted moisture variability and availability in the recent past kept insect mounds moist much longer in certain areas than in other years. Insects respond to change in thermal environment through migration, adaptation or evolution (Dunn and Crutchfield, 2006). This enables them to adapt faster to other areas to survive the climate changes and thereby increase their availability to human consumption and predators. However, confronted with both low quantity and large quantity harvests for some insects is Africa ready to take on the challenge. Insects are highly perishable, if supply is to be maintained there is need to look at processing methods and storage to cut down on post-harvest losses.

2.2 Globalization

As Africa positions itself for globalization many undesired outcomes are observed. Globalization has seen adoption of a universal cultural system largely based on western values, customs and habits including changes in food customs. It has resulted in the use of more fast foods and pre-prepared foods and the loss of traditional ways of life (Illgner and Nel, 2000). People opt for simple diets as they become busier abandoning dietary practices that are perceived as time-wasting and archaic. Entomophagy is one such practice requiring a lot of time, women and children spend a lot of time in the wild looking for insect delicacies. Diet simplification negatively impacts on human food security, nutritional balance and health.

2.3 Population growth and commercialization of agriculture

A rapidly growing human population commands increased demand for food production along with changing food production and consumption patterns. Africa's population is growing at a rate of 3 percent and the population is expected to be 2 billion by 2050 (FAO, 2010). Population pressures in the recent past have led to the evolution of agriculture from traditional to modern intensive systems. Increased globalization and urbanization has led to more arable land being lost for food production (Yen, 2009). As the human population grows and environmental degradation continues, the world faces a major problem in providing adequate animal-based protein. Consequently forests are cleared to create land for agriculture and infrastructural development. Such systems have a big bearing on biodiversity loss. Many edible insects are becoming scarce, for example, in Uganda termites are not common in urban areas. The reason behind the low occurrences is the perception about termites, the worker termite is known to destroy furniture and crops, and hence is a pest. It is therefore regarded as a menace and termataria are destroyed as soon as they show up. In large-scale agriculture they are destroyed as the land is prepared for cultivation. This compromises the quantities produced and sustainable harvest of the insects. Grasshoppers and palm weevil breed in forests and thick vegetation like forests whereas termites will breed in both dense and sparse vegetation areas. Consequently, these insects are lost and biodiversity damaged.

2.4 Pollution and use of insecticides

Populations continue to soar and industrialization becomes a viable option. As a result more greenhouse gases are produced. There is more carbon dioxide in the atmosphere and consequently in the water bodies. This means that the waters are more acid than ever before, consequently affecting the flora and fauna in water bodies. Ayeiko *et al.* (2010) also noted that the harvests of lake flies in western Kenya was lower than in the previous years. This was as a result of increased acidity of the water. Lake flies breed at the bottom of the lake, and therefore the change in PH of the water grossly affects the breeding cycle. Coupled with increased temperature, oxygen availability is compromised leading to death of the larvae. In the quest to control diseases and increase yields insecticides, pesticides and herbicides are used extensively in cities and farms. Pesticide, herbicide and fungicide use can make insects unsuitable for human consumption as pesticides accumulate in insect bodies.

3. Opportunities

Faced with several challenges, Africa can convert these challenges to opportunities. Insects in the diet clearly show the meeting point of nutrition and biodiversity in food security and sustainable development. For Africa to meet her food security and environment protection targets of the MDGs, then it is important to look at opportunities that entomophagy avails us with; however, the achievement of food security should not be at the expense of the environment. Insects present a link; they are eco- friendly as food. They consume relatively little and do not require grazing land and antibiotics like our conventional livestock (Yen *et al.*, 2008). Today livestock is one of the major contributors to greenhouse gases. As demand for animal protein increases the world over, it is probable that levels of pollution will reach their highest limits.

3.1 Cultivation of insects

The mass production of insects has great potential to provide animal proteins for human consumption, either directly, or indirectly as livestock feed. The latter could reduce energy requirements in livestock production. The use of insects as an additional source of protein could result in increased conversion efficiencies and a smaller environmental footprint in our livestock production, especially if closed systems can be developed at the village or farm level (Steinfeld *et al.,* 2006).

Insects are easy to raise and to harvest, and they are highly nutritious to eat. They have higher food conversion efficiency than more traditional meats. When reared at 30°C or more, and fed a diet of equal quality to the diet used to rear conventional livestock, house crickets show a food conversion twice as efficient as pigs and broiler chicks, four times that of sheep, and six times higher than steers when losses in carcass trim and dressing percentage are counted (Jharna Chakravorty, 2009). Protein production for human consumption would be more effective and cost fewer resources than animal protein. It is therefore important to rear or cultivate the most preferred edible insects, especially those with high nutrition value in home gardens with application of modern tools and techniques. Success stories of insect rearing are seen in the Lao People's Democratic Republic and Japan, where crickets, bugs and many other insects are harvested in home gardens (FAO, 2010; Toms and Nonaka, 2005). For this to be possible it is important to understand different cultures and indigenous knowledge.

3.2 Promote indigenous knowledge systems (IKS)

Communities that practise entomophagy have ingrained traditional knowledge and practices on how to harvest and use food insects. With changing food habits communities lose valuable traditional knowledge as such knowledge and practices are considered outdated and primitive by the younger generations. Incorporated in this knowledge system are elements that promote and favour responsible and respectful use of nature. Transmitting traditional values and wisdom to children and teenagers is important; experience shows that across many fields a combination of customary knowledge and approaches has tremendous benefits and values towards understanding science and modern trends. South Africa has taken on promoting indigenous knowledge of diets and harvesting insects into the classrooms. In their outcome-based education system, children are taught at an early stage the importance of consuming insects and sustainable harvesting for food security. They are taught about complex life cycles of the common edible insects like the mopane worms and the stink bugs (Toms and Nonaka, 2005). It is important for the harvesters to understand the complex life cycles as many insects are consumed at different stages of the life cycle. Understanding that if a particular stage is overly consumed it will lead to loss of a particular insect from the ecosystem is very important. Understanding that destruction of termataria or palm trees (forests) will lead to no harvest of white ants or palm weevil respectively is grossly important in sustainable use of resources. In northern Uganda, termataria are owned by families in grazing grounds and are jealously guarded from intruders who are considered thieves. Therefore promotion of sustainable harvesting for food security and complex life cycles of insects through the use of IKS should be adopted.

In east Africa for example, natives will tell the type of edible white ants by the type of termatarium and therefore different species of edible white ants are harvested in different ways. Great care is taken to ensure that the termataria are not destroyed. Such knowledge is not documented but is passed on by word of mouth from generation to generation. However some methods involve destroying the vegetation around the termataria and in the case of palm weevil, palm trees are destroyed. Promoting sustainable use and harvesting methods is key in IKS as well as enabling the harvesters to harvest large quantities. Traditional knowledge along with nutrition education are therefore essential foundations for advancing entomophagy, but it also has to address food security and food safety issues (Yen *et al.*, 2009).

3.3 Trade and value addition

Collection of food insects is a good source of income especially for the women as they require little capital input if gathered by hand. Insects are widely offered in local village markets, while some preferred species like grasshoppers in east Africa, mopane worms in southern Africa reach urban markets across borders. Agea *et al.* (2008) noted that grasshoppers in Kampala and Masaka, were a major source of income to the harvesters who were mainly women. Many of the harvesters noted that trade in insects had actually improved their livelihoods. However, the harvesters target is always to sell the day's catch, sometimes at lower prices because edible insects are highly perishable. It is important to add value and improve preservation methods in order to fetch more revenue and also cater for all year availability.

Elsewhere in the world, as the popularity of entomophagy grows, restaurants have opened that cater specifically to those who enjoy entomophagy. Restaurants in Singapore serve larvae and scorpions and seat sell-out crowds nightly. In some countries insects are canned, exported and sold in foreign supermarkets all year round. Therefore there should be an effort to increase the insects' commercial value as food and feed for livestock especially chicken and availability on demand in a sustainable manner. This will in the long run serve a twin purpose of insect (natural resource) use as food (food products and feed) and conservation (Jharna Chakravorty, 2009).

4. Conclusion

Insects form a large form of biodiversity in diets. It is therefore important to note that nutrition biodiversity also serves as a safety net to vulnerable households during times of crisis, presents income opportunities to the rural poor and sustains productive agricultural systems. Therefore maintenance of biodiversity is essential for the sustainable production of food and other agricultural products and provides benefits to humanity like food security, nutrition and livelihoods.

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References

Agea, G., Biryomumaisho, D., Buyinza, M., and Nabanoga, N. G., 2008. Commercialisation of Ruspolia nitidula (Nesnene grasshoppers) in Central Uganda. African Journal of Food, Agriculture Nutrition and development 8 (3): 319-332.

Ayieko, M. A., Ndong'a M. F. O and Tamale, A., (2010). Climate change and the abundance of edible insects in the Lake Victoria Region. Journal of Cell and Animal Biology Vol. 4 (7), pp. 112-118.

Bodenheimer. F.S., (1951). Insects as human food. The Hague, Netherlands. W. Junk Publishers, 1951.

Dunn. D, and Crutchfield, J.P., (2006). Insects, Trees, and Climate: The bioacoustic ecology of deforestation and entomogenic climate change. Santa Fe Institute Working paper New Mexico, 06: 12-30.

FAO. (2010) Nutrition and biodiversity, Agriculture for biodiversity for agriculture.

Huis, Van A., (2003). Insects as food in Sub-Saharan Africa. Insect Science and its application; 23 (3): 163-185.

Illgner P, and Nel E (2000). The geography of edible insects in Sub-Saharan Africa: a study of the Mopane caterpillar. The Geographical Journal 166: 336–351.

Jharna Chakravorty., (2009). Entomophagy, an ethnic cultural attribute can be exploited to control increased insect population due to global climate change: a case study.

Meyer-Rochow, V.B., Kenichi, N., and Somkhit, B., (2007). More feared than revered: Insects and their impact on human societies (with some specific data on the importance of entomophagy in a Lotian setting). Entomol. Heute; 191-23.

Rattle, H.T., (1985). Temperature and insect development. Environmental Physiology and Biochemistry of insects. (Hoffman KH Ed.), Springer-Varlag, Berlin, pp. 33-65.

Saunders, A., (2008). FAO serves up edible insects as part of foodsecurity solution. Mediaglobal, (February, 2008), United Nations Secretariat, New York, FAO Rome.

Steinfeld, H., Gerber. P., Wassenaar, T., Castel. V., Rosales. M., and de Haan, C., (2006) Livestock's Long Shadow: Environmental Issues and Options. FAO, Rome.

Toms. R., and Nonaka. K., (2005). Harvesting of insects in South Africa and Japan-Indigenous Knowledge in the Classroom. http://www.scienceinafrica.co.za/2005/july/edibleinsects.htm

Yen A., 2008. Entomophagy and insect conservation: some thought for digestion. Journal of insect conservation.

Yen, L. A., (2009). Edible insects: Traditional knowledge or western phobia? Entomological Research 39 (2009) 289–298.

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BIOACTIVE NON-NUTRIENT COMPONENTS IN INDIGENOUS AFRICAN VEGETABLES

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Abstract
In many African cultures, vegetables form an important part of a healthy traditional diet because of their nutritional and health benefits. Vegetables have been reported to have many health protecting properties, thus illustrating the relationship between nutrition and medicine which has long been recognized in African cultures. This study evaluated the phytochemical composition of selected indigenous vegetables in Uganda. The crude extracts of diethyl ether, 96 percent ethanol and distilled water indicated that *Amaranthus hybridus* L., *Amaranthus cruentus* L., *Solanum aethiopicum* L., *Cleome gynandra* L. and *Vigna unguiculata* L. contain alkaloids, tannins, flavonoids, saponins, carotenoids, coumarin derivatives and glucides phytochemicals. Another phytochemical, steroid glycoside, was detected in the distilled water extract of *A. cruentus*, *S. aethiopicum* and *V. unguiculata*. The quantitative analysis of the total flavonoid content in *A. hybridus*, *A. cruentus*, *S. aethiopicum*, *C. gynandra* and *V. unguiculata* showed 8.7, 12.0, 15.2, 26.4 and 10.6 g per 100 g dry weight, respectively, while the total alkaloid content showed 2.7, 3.3, 4.0, 3.8 and 1.7 g per 100 g dry weight, respectively. The phytochemical composition in the respective indigenous African vegetables justifies their therapeutic activity against a wide range of diseases. These phytochemicals have anti-oxidant, antihypertensive, antidiabetic and anti-ulcer properties that can prevent a number of diseases. With these health benefits, there is need to emphasize a diet rich in indigenous green leafy vegetables to promote health and prevent diseases in the population. There is also need for further research and value addition to indigenous African vegetables as a potential source of drugs or medicines.

1. Introduction

In many African cultures, vegetables are widely consumed together with starchy staple foods such as bananas, millet, sorghum, maize, cassava and sweet potatoes. Vegetables form an important part of a traditional African diet, since they have enormous nutritional and health benefits, besides adding taste and palatability to food (Akubugwo *et al.*, 2008; Rubaihayo, 1997). Consumption of vegetables is believed to play a significant protective role against degenerative diseases such as cancer, chronic cardiovascular diseases and high cholesterol levels (Adefegha and Oboh, 2011; Agudo *et al.*, 2002).

In fact, it is reported that consumption of fruits and vegetables lowers total cholesterol (Dragsted *et al.*, 2006), while consumption of 400 g of fruits and vegetables per day is recommended by WHO/FAO for prevention of chronic cardiovascular diseases (Kanungsukkasem *et al.*, 2009). However, consumption of vegetables in sub-Saharan Africa still lags behind other regions, yet it is endowed with a high diversity of edible vegetables (Habwe and Walingo, 2008). Of the 1 000 edible green vegetables species in sub-Saharan Africa, Uganda has about 600 local vegetable species (Ssekabembe *et al.*, 2003).

A study carried out by Bukenya-Ziraba *et al.* (1999) reported 38 different types of vegetables sold in different major markets of Kampala, Uganda. Of the reported vegetable species, *Amaranthus* sp., *Solanum* sp., *Capsicum* sp. and *Cleome gynandra* are identified as the most commonly consumed vegetable species (Ssekabembe *et al.*, 2003). Although vegetables are consumed widely, they are prepared differently, depending on preferences and indigenous knowledge of the local communities.

In Uganda, vegetables are prepared by steaming, mashing or boiling with staple food to make a local dish (*Katogo*), frying with edible oil and pasting with groundnuts or sesame (Musinguzi *et al.*, 2006). Frying is the most popular method of vegetable preparation for eating in urban centres of Uganda and has been adopted in rural areas as well. Vegetables are eaten as food in form of sauce, raw as snack and salads or even side dishes of the main meal (Musinguzi *et al.*, 2006). The nutrition and bioactive composition of vegetables make them very important in the household, especially during times of food shortage.

Vegetables have been found to improve nutrition, boost food security, foster rural development, support sustainable land care and offer health protecting properties (Agea *et al.*, 2010). This illustrates the relationship between nutrition and medicine that is recognized in African cultures. Epidemiological studies indicate a relationship between consumption of vegetables and prevention of chronic diseases such as cancer, hypertension and heart diseases (Katt, 2005; Pierini *et al.*, 2008). Phytochemicals found in vegetables such as flavanoids exert a protective effect against these chronic diseases (Franke *et al.*, 2004)

Although many of the indigenous vegetables are available and consumed in Africa, little is known about their phytochemical composition that contributes to their therapeutic effects. Recent trends show that public health experts are interested to know the composition of vegetables to provide proof of their health benefits. This study evaluated the phytochemical composition of selected indigenous vegetables in Uganda.

2. Materials and methods

2.1 Sample collection

About 5 kg of fresh, sorted and disease-free vegetable leaf samples that included: *Amaranthus hybridus*, *Amaranthus cruentus*, *Cleome gynandra*, *Solanun aethiopicum* and *Vigna unguiculata*, were purchased from a market vendor in Kampala, Uganda in June 2009. These vegetable species are among the most grown and consumed vegetables in Uganda (Bukenya-Ziraba *et al.*, 1999; Ssekabembe *et al.*, 2003). The vegetable species were scientifically identified by a taxonomist. Voucher specimens were prepared and deposited at the herbarium of the Natural Chemotherapeutics Research Institute, Ministry of Health, Kampala, Uganda for future reference.

2.2 Sample preparation

The vegetable samples were cleaned with distilled water and dried to a constant weight in vacuum oven (40–50°C). The dry leaves were pulverized into powder and kept in a cool dry place until extraction was completed.

2.3 Extraction and analysis

The leaf powder of each vegetable sample was divided into two portions. One portion was used for qualitative phytochemical screening and another portion for quantitative determination of total flavanoids and total alkaloids. The sample portion for phytochemical qualitative screening (200 g) was analysed using standard methods reported by Culei (1982) and Idu *et al.* (2006). In brief, diethyl ether and 96 percent ethanol solvents were used in soxhlet apparatus extraction of the samples in a successive manner. The residue of soxhlet extraction was then boiled in distilled water to extract with water. The extracts of diethyl ether and ethanol were then concentrated under reduced pressure with rotary evaporator, while the water extract was filtered. All the extracts of diethyl ether, ethanol and water were then subjected to qualitative phytochemical screening.

The other vegetable sample portion was used for determination of total flavanoids and total alkaloids using standard method reported by Edeoga *et al.* (2005). For determination of total flavanoids, 10 g of vegetable leaf powder was put into a round bottom flask and repeatedly extracted with 80% aqueous methanol (100 ml) at room temperature for 4 hours with regular shaking. The solution was then filtered using whatman filter paper no. 1 and the filtrate concentrated under reduced pressure with rotary evapourator at 50°C. The concentrate was then evaporated to dryness in a vacuum oven at 50°C and total flavanoids were determined gravimetrically.

All analyses were done in triplicate.

In determination of total alkaloids, 5 g of dry vegetable leaf powder was weighed, carefully transferred into a beaker and 10 percent acetic acid (200 ml) in ethanol added. The mixture was covered and allowed to stand for 4 hours and filtered. The filtrate was concentrated on a hot water bath to one-quarter of the original volume. The concentrate was allowed to cool at room temperature and concentrated ammonia added dropwise until precipitation was complete. The solution was allowed to settle and the precipitates collected by filtering using whatman filter paper no 1. The precipitate on the filter paper was washed with dilute ammonia and a residue dried in a vacuum oven at 50°C and weighed. The total alkaloids were determined gravimetrically. All analyses were also done in triplicate.

3. Results and discussion

The results of the phytochemical composition of selected indigenous African vegetables are presented in Table 1. The phytochemical components in the dry vegetable leaf crude extracts included alkaloids, tannins, flavonoids, saponins, carotenoids, coumarin derivatives and glucides. Phytochemicals have therapeutic properties such as anti-allergic, anti-inflammatory, antihypertensive, antidiabetic, anti-oxidant, anti-ulcer, anti-cancer activity which are beneficial to human health (Dembinska-Kiec *et al.,* 2008; Issa *et al.*, 2006). Specifically, tannins, flavanoids and coumarins are known anti oxidants which are essential in the prevention of complicated degenerative diseases such as cancer, cardiovascular, alzheimers and parkinson (Ahmad *et al.*, 2006; Tungjai *et al.*, 2008).

Dietary anti-oxidants prevent production of free radicals by chelating reactive species produced in the body that are responsible for causing degenerative diseases (Adedayo *et al.*, 2010; Adefegha and Oboh 2011; Okigbo *et al.*, 2009). It is also known that alkaloids, flavanoids, tannins, reducing compound, sterols and triterpenes have good antimicrobial properties that are essential in the management of diseases such as malaria, fever, diarrhea and respiratory tract infection (Adebayo-Tayo and Adegoke, 2008; Kubmarawa *et al.*, 2007).

Therefore, consumption of *A. hybridus*, *A. cruentus*, *S. aethiopicum*, *C. gynandra* and *V. unguiculata* provides a diet with health benefits. It is necessary for policy-makers to consider indigenous African vegetables as important resources for human nutrition and improved health of the population. This emphasizes the need to sensitize the population on benefits of a vegetable diet in disease prevention, thus reduce morbidity.

Table 1. Phytochemical composition of selected African edible vegetables.

Species of vegetable	*A. hybridus*	*A. cruentus*	*S. aethiopicum*	*C. gynandra*	*V. unguiculata*
Diethyl ether extract					
Sterols and triterpenes	(–)	(–)	(–)	(–)	(–)
Carotenoids	(+)	(+)	(+)	(+)	(+)
Basic alkaloids	(+)	(+)	(+)	(+)	(+)
Flavanoid aglycones	(+)	(+)	(+)	(+)	(+)
Emodols	(+)	(–)	(–)	(–)	(–)
Coumarins	(–)	(–)	(+)	(+)	(+)
96% ethanol extract					
Tannins	(+)	(+)	(+)	(+)	(+)
Reducing compounds	(–)	(–)	(–)	(–)	(–)
Alkaloids	(+)	(+)	(+)	(+)	(+)
Coumarin derivatives	(+)	(+)	(+)	(+)	(+)
Anthracenosides	(–)	(–)	(–)	(–)	(–)
Steroid glycosides	(–)	(+)	(+)	(–)	(+)
Flavonosides	(+)	(+)	(+)	(+)	(+)
Saponins	(+)	(+)	(+)	(+)	(+)
Water extract					
Polyuronides	(–)	(–)	(–)	(–)	(–)
Reducing compounds	(–)	(–)	(–)	(–)	(–)
Glucides	(+)	(+)	(+)	(+)	(+)
Starch	(–)	(–)	(–)	(–)	(–)
Saponins	(+)	(+)	(+)	(+)	(+)
Tannins	(+)	(+)	(+)	(+)	(+)
Alkaloid salts	(–)	(–)	(–)	(–)	(–)

Key: (+) present or detected (–) not present or not detected

Apart from preventing diseases, vegetables can be a source of drugs for treatment. Several drugs have been developed from plant extract. An alkaloid (quinine) and a sesquiterpene (artemesinin) that is used in the treatment of complicated malaria have been developed from the bark of Cichona tree and *Artemisia annua* plants, respectively. This therefore means that vegetables can also be a potential source of phytochemicals that can be developed into drugs for prevention or treatment of diseases (Table 2). There is also need to understand the chemical compounds in indigenous African vegetables that can be scientifically investigated and developed into potential drugs. Further research is needed to isolate and determine specific chemical compounds in the identified alkaloids and flavanoids that can be developed into drugs.

Table 2. Total flavanoids and alkaloids in selected African edible vegetables.

Vegetable species	Total flavanoids (%)	Total alkaloids (%)
A. hybridus	8.7±0.1	2.7±0.3
A. cruentus	12.0±0.3	3.3±0.0
V. unguiculata	10.6±0.1	1.7±0.1
C. gynandra	15.2±0.2	4.0±0.3
S. aethiopicum	26.4±0.6	3.8±0.2

4. Conclusion and recommendations

Based on the findings of this study, it can be concluded that a diet rich in some indigenous African vegetables can be of therapeutic use for prevention and treatment of diseases as well as a potential source of drugs. Therefore, policy-makers need to promote vegetable consumption and conduct further scientific research on indigenous African vegetables to isolate chemical compounds that can be developed into drugs.

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References

Adebayo-Tayo, B. C., & Adegoke, A. A.(2008). Phytochemical and microbial screening of herbal remedies in Akwa Ibom State, South Southern Nigeria. Journal of Medicinal Plants Research. 2(11), 306-310

Adedayo, B.C., Oboh, G and Akindahunsi, A.A. (2010). Changes in the total phenol content and antioxidantproperties of pepperfruit (Dennettia tripetala) with ripening. African Journal of Food Science 4(6),. 403 - 409,

Adefegha, S.A., & Oboh, G. (2011). Cooking enhances the antioxidant properties of sometropical green leafy vegetables. African Journal of Biotechnology 10 (4), 632-639

Agea, J.B., Kimondo J.M., Okia, C. A., Abohassan, R.A.A., Obua, J., Hall, J., Teklehaimanot, Z. (2010). Contribution of wild and semi food plants to overall house hold diet in Bunyoro-Kitara Kingdom, Uganda . Agricultural Journal 6 (4), 134-144

Agudo, A., Slimani, N., Ocke,´ M.C., Naska, A., Miller, A.B., Kroke, A., Bamia, C., Karalis, D., Vineis, P., Palli, D., Bueno-de-Mesquita, H.B., Peeters, P.H.M., Engeset, D., Hjartaker, A., Navarro, C., Martınez, G.C., Wallstrom, P., Zhang, J.X., Welch, A.A. (2002). Consumption of vegetables, fruit and other plant foods in the European Prospective Investigation into Cancer and Nutrition (EPIC) cohorts from 10 European countries. Public Health Nutrition: 5(6B), 1179–1196

Ahmad, I., Aqil, F., Owais, M. (2006). Modern Phytomedicine. Turning medicinal plants into drugs pp 247-353

Akubugwo, I. E., Obasi, N.A., Chinyere, G.C., Ugbogu, A. E. (2008). Mineral and phytochemical contents in leaves of Amaranthus hybridus L and Solanum nigrum L. subjected to different processing methods. African Journal of Biochemistry Research 2 (2), 040-044

Bukenya-Ziraba, R., Tabuti, J.R.S., Schippers, R., Ssenteza, J., Feredy N.(1999). Socio economic importance of indigenous vegetables in peri urban areas of Kampala (Uganda). Lidia 4 (5), 121-132

Culei, I. (1982). Methodology for the analysis of vegetable drugs. Practical Manual on the industrial Utilisation of Medicinal and Aromatic Plants Center Building, Romania pp. 67-81

Dembinska-Kiec, A., Mykkanen, O., Kiec-Wilk B., Mykkanen, H. (2007).Antioxidant phytochemicals against type 2 diabetes. British Journal of Nutrition , 99, (E-Suppl. 1); ES109–ES117

Dragsted, L.O., Krath, B., Ravn-Haren, G., Vogel, U.B., Vinggaard, A.M., Jensen, P.B., Loft, S., Rasmussen, S.E., Sandstrom, B-M., Pedersen, A. (2006). Symposium on 'Phytochemicals' Biological effects of fruit and vegetables. Proceedings of the Nutrition Society , 65, 61–67

Edeoga, H.O., Okwu, D.E., Mbaebie, B.O. (2005). Phytochemical constituents of some Nigerian medicinal plants. African Journal of Biotechnology Vol. 4 (7), 685-688

Franke, A.A., Custer, L.J., Arakaki, C., Murphy, S.P. (2004). Vitamin C and flavonoid levels of fruits and vegetables consumed in Hawaii. J. Food Comp. Anal. 17, 1-35.

Habwe, F.O., & Walingo, K.M. (2008). Food Processing and Preparation Technologies for Sustainable Utilization of African Indigenous Vegetables for Nutrition Security and Wealth Creation in Kenya. International Union of Food Science & Technology. Pp 1-9

Idu, M., Oronsaye, F.E., Igeleke, C.L., Omonigho, S.E., Omogbeme, O.E., Ayinde, B.A. (2006) Prelimary Investigation on the phytochemical and Antimicrobial Activity of Senna alata L., leaves. Journal of Applied Sciences 6 (11), 2481-2485.

Issa, A.Y.,Volate, S.R, Wargovich, M.J. (2006).The role of phytochemicals in inhibition of cancer and inflammation:New directions and perspectives. Journal of Food Composition and Analysis. 19, 405–419

Kanungsukkasem, U., Ng, N., Minh, H.V., Razzaque, A., Ashraf, A., Juvekar, S., Ahmed, S.M., Bich, T.H. (2009). Fruit and vegetable consumption in rural adults population in INDEPTH HDSS sites in Asia. NCD supplement. COACTION.2,10.3402/gha.v2i0.1988

Katt , W. (2005). Effect of production and processing factors on major fruits and vegetables antioxidants. Journal of Food Science. R. Concise reviews/hypotheses in food science. 70 (1), NR11-19.

Kubmarawa, D., Ajoku, G.A., Enwerem, N.M., Okorie D.A. (2007).Preliminary phytochemical and antimicrobial screening of 50 medicinal plants from Nigeria. African Journal of Biotechnology 6 (14), 1690-1696

Musinguzi, E., Kikafunda, J.K., Kiremire, B.T.(2006). Utilization of indigenous food plants in uganda: a case study of south-western Uganda . African Journal of Food Agriculture Nutrition and Development, 6 (2), 1-21.

Okigbo, R.N., Anuagasi, C.L., Amadi, J.E. (2009). Advances in selected medicinal and aromatic plants indigenous to Africa. Journal of Medicinal Plants Research 3(2), 086-095.

Pierini, R., Gee, J.M., Belshaw, N.J., Johnson, I.T. (2008). Flavonoids and intestinal cancers. British Journal of Nutrition, 99 (E-Suppl. 1), ES53–ES59.

Rubaihayo, E. B. (1997). The Contribution of Indigenous Vegetables to the household food security in Uganda. African Crop Science Conference Proceedings. 1, 1337-1340.

Ssekabembe, C.K., Bukenya, C., Nakyagaba, W. (2003). Traditional knowledge and practices in local vegetable production in central Uganda. Afr. Crop Sci. Conf. Proc. 6, 14-19.

Tungjai, M., Poompimon, W., Loetchutinat, C., Kothanand, S., Dechsupa, N. (2008). Spectrophotometric Characterization of Behavior and the Predominant Species of Flavonoids in Physiological buffer: Determination of solubility, lipophilicity and anticancer efficacy. Open Drug Deliv. J., 2, 10-19.

ACHIEVEMENTS IN BIODIVERSITY IN REGARD TO FOOD COMPOSITION IN LATIN AMERICA

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Abstract
Biodiversity in food composition supplies human beings with both macro-and micronutrients as well as the bioactive compounds they require to maintain optimum physiological conditions throughout life. Latin America has a high level of natural food biodiversity, but at the same time obesity and malnutrition in children are present. The foods a community consumes is an excellent tool to be used for learning about its history and culture. Before Christopher Columbus's trip in 1492, there were many different cultural groups in Latin America, including three great empires from the north to the extreme south: the Mayas, the Aztecs and the Incas. A retrospective view of the native foods cultivated by these ancient cultures will be presented considering their biodiversity and composition. Three foods, which maintain their importance until today, were basic in these three empires: corn (*Zea mays*), yuca (*Manihot esculenta, Manihot utilissima*) and potatoes (*Solanum tuberosum*). These were wisely complemented with other native foods with high protein content, such as beans (*Phaseolus vulgaris*), other seeds, vegetables and many fruits. After 1492, Spanish and Portuguese navigators carried at least 22 foods back to Europe, Africa, Asia and Oceania, transforming previously colourless and monotone diets, and contributing to better health while saving many lives with their nutrients and bioactive compounds. Other traditional foods have been forgotten or underutilized, and it is time to rediscover them. These foods can help restore a healthy life to "developed society", which is suffering from inadequate management of its daily diet, leaving many children in the world still lacking the minimum levels of nutrients needed for survival. Latin American governments and Latin American branches of LATINFOODS through FAO TCP projects have made important efforts towards generating new food composition data focused on the twin priorities of biodiversity and nutrition.

1. Introduction

Biodiversity in food composition supplies human beings with both macro- and micronutrients and the bioactive compounds they require to maintain optimum physiological conditions throughout life. Distortions in diets in some Latin American and Caribbean countries lead to obesity and malnutrition in children, indicating that opportunities open to different sectors of the population are not equal, even as statistics say that food production in each individual country is sufficient (FAOSTAT, 2010; FAO, 2010a).

According to the FAO Declaration (2010b), efforts must be made by government agencies, international institutions, the food industry and academia towards generating food composition data for native components and sustainable diets. INNFOODS through LATINFOODS Net and their Latin American branches are the best technical platforms available for the development of programmes and policies that individual governments can use in this regard.

2. Culture and foods and their social impact

The foods a community consumes is an excellent tool to be used for learning about its history and culture. One or two basic foods should be rich in carbohydrates to guarantee primary energy requirements, with these complemented by other foods belonging to the country's local ecology. These basic foods represent emblematic meals, always present at all social activities, and they must be maintained and protected as they are part of the culture and in some cases of the religious traditions of these societies. This harmonious link between man and food reflects a people's actions, culture and life. In Latin America, there are many examples of the strong relationship between man and his environment, foods and divinities. Before Christopher Columbus's arrival in 1492, many different cultural groups were settled in this large land mass, including from the north to the south the three powerful empires of the Mayas, Aztecs and Incas, representing cultures that were more than 3 000 years old. They had well-structured civil organizations, advanced knowledge in science, arts, architecture, astronomy, agriculture and irrigation, active commerce, and natural laws directing daily life according to their divinities. Total population was estimated to be at about 60 000 000 inhabitants, with the Aztec Empire the largest at close to 20 000 000; Tenochtitlan, where Mexico City now stands, had more than 500 000 inhabitants. More than 200 languages were spoken, and native people had deep contact with and knowledge of nature. They "domesticated" the best lines they could obtain from their wild plants, taking care of their own natural biodiversity (Lucena, 2005).

Three foods, which maintain their importance and wide biodiversity until today, were basic for feeding the large populations in these three empires: corn (*Zea mays*), yuca (*Manihot esculenta*, *Manihot utilissima*) and potatoes (*Solanum tuberosum*). Corn (*Zea mays*), the "sacred" food, was basic for the Mayan, Aztec and Incan populations, and its importance is maintained until today as it continues to be the basic food for many typical meals in Latin America. The oldest evidence of its cultivation is found in the Tehuacán valley, Mexico, from about 7 000 years ago. Corn means "support of the life", and it had great importance in religious ceremonies, celebrations and nutrition.

The Aztecs said that "corn is our body, our blood and bones". Corn was the first Latin America species introduced to Europe at the end of the fifteenth Century. It maintains its great biodiversity in grain colour: white, yellow, deep yellow, brownish, deep violet (FAO, 1993; Tapia, 1997), and is a good source of Zeaxantina and Luteina (Kimura *et al.*, 2007). "Nixtamalization" is an ancient procedure still used in Mexico to improve the availability of minerals, vitamin B and protein in corn flour, giving the Aztecs a sustainable diet based mainly on nixtamal, plus beans, pumpkin, hot chili, tomato, prickly pears etc., and it is considered nutritionally satisfactory (FAO, 1993). Corn germ oil is a good source of linoleic acid (close to 60%), tocopherols, and phytosterols (Moreau *et al.*, 2009).

Yuca root, cassava or manioc was the basic food in the middle tropical region. One variety was sweet (*Manihot utilissima*), and one bitter (*Manihot esculenta*). The latter variety is detoxified for human consumption, and is the base for preparing "tapioca" flour. Its history starts in around the year 2700 BC. The sweet variety is found from the Pacific to Mexico and Central America, and the bitter one from Paraguay to northeast Brazil. Portuguese navigators introduced yuca to Africa in the seventeenth century, after corn, and yuca then expanded to the Indian Ocean Islands, India, Asia and the Pacific Islands. Yuca is one of the more widely cultivated plants in the world. With its low costs for production and processing, high yield, and low commercial importance, it is a food dedicated mainly to private consumption in the local communities in developing countries. In Paraguay and in Brazil, one of the largest producers of yuca, this native root is still a food consumed daily in different forms. In Brazil, it is the principal ingredient in two symbolic foods, "farofa" and "pirão". In Colombia and Venezuela, yuca also has great importance (Ospina and Ceballos, 2002; Cartay, 2004). Yuca is a high source of carbohydrates, some minerals, and vitamins (TACO, 2006).

Potatoes (*Solanum tuberosum*) are the third basic food. Originating in South America, high in the Lake Titicaca region of the Andes Mountains at an altitude of 3 800 m, the potato has been consumed in the Andes for about 8 000 years. Maintaining its leadership position in the Andes valleys together with corn (Tapia, 1997), Andean potatoes have great biodiversity, with different shapes, sizes and skin colours: green, yellow, pink, red and violet. Potatoes are an important source of energy, vitamin C, minerals, carotenoids, anthocyanins in the peel and flesh (Schmidt-Hebbel *et al.*, 1992; Andre *et al.*, 2007a; Andre *et al.*, 2007b; Moenne-Locoz, 2008; Burmeister *et al.*, 2011). There are more than 5 000 varieties in the Andes region and more than 200 Andean potato varieties in Jujuy northwest of Argentine 26–28° parallel latitude south. Seven varieties have been analysed, (Jimenez *et al.*, 2009a, b), with the best in regard to carbohydrates and protein being the "Imilla Colorada" variety (Figure 1).

Figure 1. Native potatoes from Andean northwest Jujuy, Argentine, parallel 26 – 28º latitude south, cultivated at 3000 m altitude.

Another old native source of potatoes is located in the extreme south of Chile, in the Chiloe Island at the 41– 43° parallel latitude south. These also present great biodiversity in shape, peel colour, and flesh, and are a good source of vitamin C, flavonoids, and anthocyanin pigments (Moenne-Locoz, 2008) (Figure 2).

The two varieties analysed, "Bruja" and "Michuñe negro", have dark skins and violet flesh, and they provide more protein, ash, vitamin C, total flavonoids and anthocyanin, and fewer carbohydrates than the normal Chilean commercial variety potato (Schmidt-Hebbel *et al.*, 1992). Sixteenth century Spanish navigators picked large amounts of potatoes in the Chiloe Island for food for their long voyages, and while they did not know it, the potatoes' vitamin C content saved the lives of many mariners by preventing scorbutic disease.

Chiloe potatoes are now in the Chilean market as "Rainbow potatoes" from the South of the World (Figure 3).

Figure 3. Commercial native potatoes "Arco Iris" (Rainbow) from the "South of the World", Chiloe Island, Chile, raw and boiled.

Figure 2. Native potatoes from Chiloe Island, Chile, parallel 41 – 43° latitude south, cultivated at sea level, raw, halved and potato chips home made.

The book "International Year of the Potato" is dedicated to this old and nutritious food which today can solve hunger problems in the world and contains quite extensive information. History tells us that the Spanish carried it to Europe in the sixteenth century, and it quickly spread across the globe from China's Yunnan plateau to the steppes of the Ukraine, changing the history of food in the Old World. It is the world's number one non-grain food commodity, production reached a record 325 million tonnes in 2007, China is the world's principal producer (FAO, 2008). Our native potato is unique in the world, and represents a real treasure that needs to be appreciated in Latin America and taken care of.

These three basic native foods that are rich in carbohydrates were wisely complemented with other native foods with a high content in protein, such as beans (*Phaseolus vulgaris*). With evidence of cultivation from 500–8 000 years ago, beans are still present in daily diets from North to South America. They also present a high level of biodiversity in peel colour, shape and composition, and are a source of bioactive components, their oil 2 percent, a good source of linolenic acid, about 40 percent (TACO, 2006).

In the Andes Region, other native seeds complemented the Incan diet, such as quinoa (*Chenopodium quinoa*), with more protein and fat than cereals. The four limiting amino acids in a mixed human diet, lysine, sulphurs (methionine and cystine), threonine and tryptophan, are present in higher amounts than in wheat, confirming the high quality of its biological protein (Bascur and Ramelli, 1959; Tapia, 1997; Schmidt-Hebbel *et al.,* 1992), the 7.4% oilseed content is 7.8% linolenic, 50% linoleic, 23% oleic, and 11% palmitic, good n-6:n-3 ratio of 6.4:1 according to current recommendations (FAO, 2010c; Masson and Mella, 1985). "High Plateau" quinoa, a whole plant food, is a good source of vitamins and minerals and needs more research. Its plants and seeds present great biodiversity, and they grow at a high altitude, 3 000–4 000 m above sea level, in very aggressive conditions, including low temperatures, strong winds, high sun irradiation, salty soil.

They develop bioactive compounds, such as flavonoids and anthocyanin, as defence mechanisms. Quinoa leaves and seeds are pink, green, yellow, brownish, deep black colour, and they are highly valued in external markets (Tapia, 1997). Tarwi or lupine seeds (*Lupinus mutabilis*), the bitter variety, have their alkaloids taken out for human consumption (Tapia, 1997). The composition of tarwi seeds is close to that of soybeans. Their fatty acids are a good source of linolenic acid 9%, and linoleic acid 21%, with a n-6:n-3 ratio of 2.2:1. Between 200 m and 4 000 m in altitude, other tubers were also grown, such as oca (*Oxalis tuberose*) (Tapia, 1997). Six varieties, with different shapes and peel colours of pink, yellow, deep violet and white, were analysed (Jimenez and Sammán, 2009).

The pink peel variety has the best composition. Some roots other than yuca have also been important in Andean and Central American diets, such as sweet potato (*Hipomea batata*). With its rustic cultivation and high productivity, it saved the lives of many people in catastrophic situations in Europe and Asia. It is a good source of carbohydrates, fibre, and β-carotene (Schmidt-Hebbel *et al.*, 1992; Kimura *et al.,* 2007).

Amaranto or kiwicha (*Amaranthus caudatus*) also complemented the protein in the Andean diet (Tapia, 1997). Fourteen samples of genetic material from four amaranto seed varieties (*A. mantegazzianus, A. caudatus, A. cruentus , A. hipochondriacus*) were analysed, including the fatty acid composition of the seed oil, before reintroducing them in Jujuy, Argentina. The best variety was *A. caudatus* CT 10, which is highly resistant to extreme drought (Acuña *et al.*, 2007). The fatty acid groups were 24% saturated, 29% monounsaturated and 44% polyunsaturated. Squash or pumpkin (*Cucurbita maxima*), a good source of β-carotene (Kimura *et al.,* 2007; Azebedo-Melero and Rodriguez-Amaya, 2007), together with corn and beans continues to be a part of the basic diet in Latin American cultures. Incan, Mayan and Aztec diets were balanced in quantity and quality in carbohydrates, protein, fibre, fats and good n-6:n-3 ratios, which is now difficult to attain, as well as in terms of micronutrients such as minerals, vitamins, and bioactive compounds. It was a more vegetarian diet, animal protein was not so important, in the north it came from native Mexican turkey (*Gallopavo meleagis*) or Guajalote, in the Andean Region from lama (*Lama glama*) and cuy (*Cavia porcellus*) and in general, from rivers, lakes and the sea (Tapia, 1997; Bengoa, 2001).

3. Latin American food biodiversity related to food composition and health

From ancient times, Latin America has been a good example of food biodiversity. PACHAMAMA, the Mother Earth to the Incan culture, opens up each year offering all kinds of fruits, roots, tubers, leaves, flowers, seeds and species, each one maintaining its biodiversity unchanged over the centuries. Now it is our turn to do research and to discover the secrets of their healthy components. A brief comment on 22 native foods cultivated by these ancient cultures and introduced to the whole globe by Spanish and Portuguese navigators after 1492 now follows, all of which have high biodiversity, and have changed the colourless and monotone diet of the Old World. Like a rainbow that settled overseas forever, they are present on the tables of millions of families around the world on a daily basis, brightening them with their attractive colours: deep reds, oranges, yellows, pinks, deep greens, deep violets, black, white and browns.

They not only enhance taste and flavour, but offer health and life to consumers through their contributions of vegetable proteins, carbohydrates, fats, vitamins, minerals and natural antioxidants (Hoffmann-Ribani *et al.,* 2009; Rodriguez-Amaya *et al.,* 2008). Corn (*Zea mays*), beans (*Phaseolus vulgaris*), yuca (*Manihot esculenta, Manihot utilissima*), potatoes (*Solanum tuberosum*), sweet potato (*Hipomea batata*) and squash or pumpkin (*Cucurbita maxima*) have been commented on. Tomato (*Lycopersicum esculentum* Mill.), the best source of lycopene, conquered Italy, and became a daily ingredient of Italian meals. Ají or hot chili and sweet chili (*Capsicum annuum*), changed gastronomy in Asian countries, capsaisina is responsible for hot taste. Exotics fruits from the tropical zone, include avocado (*Persea americana* Mill.), cherimola (*Annona cherimola* Mill.), papaw (*Carica papaya*), pineapple (*Ananas sativus* (Lindl) *Schult.*), guayaba (*Psidium guajava*), maracuyá, (*Passiflora edulis*, *Pasiflora edulis flavicarpa*).

From the Chilean forest come white strawberries (*Fragaria chiloensis*), and from Mexico, prickly pear (*Opuntia ficus-indica*) representing many options for different attractive and good tasting formats. From Brazil, two seeds, the peanut (*Araquis hypogaea*) and the cashew nut (*Anacardium occidentale* L.), can be found in the pockets of people of all ages around the world, and are high in protein and fat content. From Mexico, sunflower seeds (*Heliantus annus*) are a source of one of the most important vegetable oils produced in the world. Also from Mexico, come two spices: vanilla (*Vanilla planifolia*), a delicate natural flavouring and source of the powerful antioxidant vanillin, and rocu seeds (*Bixa orellana*) with natural red-orange bixina carotenoid food dye. From Ecuador, cocoa seeds (*Theobroma cacao*) "Food for Gods", from the Mayan word "Ka'kaw", an important beverage for the Mayans and the Aztecs, was domesticated more than 2 000 years ago and introduced to Africa and Oceania. Its seeds contain the most delicious fat in the world, impossible to duplicate, and a source of natural antioxidants (Visioli *et al*., 2009). The composition of most of these foods is in the cited literature.

New data has been generated and published in recent years in Food Composition Tables: Centro America (2006), Costa Rica: Alfaro *et al*. (2006), Blanco-Metzler *et al*. (2006), Monge-Rojas and Campos (2006), Brazil: TACO (2006), Rodriguez-Amaya *et al*. (2008), México: Villalpando *et al.* (2007), other updated Lajolo *et al.* (2000), Tablas de Composición de América Latina (2009 rev.), Schmidt.-Hebbel *et al.* (1992). Data of seeds from native Latin America fruits cultivated in Chile and their extracted fatty acid oil composition, tocopherols and phytosterols has been published: cherimola (*Annona cherimola*), papaw (*Carica pubescens*), prickly pear (*Carica ficus-indica*) (Masson *et al.*, 2008a) and native Chilean palm seeds (*Jubaea chilensis* Molina, Baillon) (Masson *et al.*, 2008b). These special oils have their own fatty acid composition and bioactive compounds, offering new raw material for food and cosmetic purposes, and they represent a real possibility to extract more value from agro waste materials that are currently not utilized.

4. Final remarks

Some traditional Latin American foods have been "forgotten" or "underutilized", it is time to rediscover them. Their great biodiversity represents an excellent source of bioactive components which can contribute to the restoration of the poor health of "developed society", which is suffering from the inadequate management of its daily diet, while also offering healthy foods to many children, who today still do not have the minimum levels of nutrients for survival.

Latin American countries must strengthen efforts to establish government policies for the generation of food composition data, including those "forgotten" or "underutilized" ancient foods high in natural biodiversity.

Project TCP/RLA/3107 (D) (2008–09), has contributed to strengthening food composition activities in Argentina, Chile and Paraguay, together with their respective governments' support, in Chile, food composition is now a part of government policy.

Efforts in this direction must be supported through agreements between the international agencies involved in food resources, nutrition, health and biodiversity, together with INNFOODS through LATINFOODS NET and their national branches, the governments involved and the private industrial sector.

References

Alfaro, T.C., Salas, M.T.P., Ascencio, M.R.(2006). Tabla de Composición de Alimentos de Costa Rica, ácidos grasos. ISBN 9968-843-172. Ed. INCIENSA. San José, Costa Rica. http://www.inciensa.sa.cr/files/refs/alimentos%20alimentos fortificados

Andre, M.C., Ghislain, M., Bertin, P., Oufir, M., Herrera, M.del R., Hoffmann, L., Haussman, J-F., Larondelle, Y., and Evers, D. (2007a). Andean Potato Cultivars (Solanum tuberosum L.) as a Source of Antioxidants and Mineral Micronutrients. J. Agric. Food. Chem, 55, 366-378.

Andre, M.C., Oufir, M., Guignard, C., Hoffmann, L., Haussman, J-F., Evers, D., and Larondelle, Y. (2007b). Antioxidant Profiling of Native Andean Potato Tubers (Solanum tuberosum L.) Reveals Cultivars with High Levels of β-Carotene, α-Tocopherol, Chlorogenic Acid, and Petanin, J. Agric. Food. Chem, 55, 10839-10849.

Azebedo-Melero, and Rodriguez-Amaya, D. (2007). Qualitative and Quantitaive Differences in Carotenoid Composition among Cicurbita moschata, Cucurbita maxima and Cucurbita pepo. J.Agr.FoodChem, 55, 4027-4033.

Bascur, L. Ramelli, T. (1959). Estudio bromatológico y biológico de la quínoa. Anales de la Facultad de Química y Farmacia, Universidad de Chile. Tomo XI, pp 43-50.

Bengoa, J.M. (2001). América Latina en la alimentación y nutrición mundial. An. Venez.Nutr. 14, 103 -108, ISSN 0798-0752.

Blanco – Metzler, A., Montero – Campos, M.A., Fernández – Piedra, M. (2006). Tabla de Composición de Alimentos de Costa Rica, ácidos grasos. ISBN 9968-843-15-D. Ed. INCIENSA. San José, Costa Rica. http://www.inciensa.sa.cr/files/refs/alimentos%20macronutrientes y fibra dietética

Burmeister, A., Bondiek, S., Apel, L., Künhe, C., Hillebrand, S., Fleischmann, P. 2011. Comparison of carotenoid and anthocyanin profiles of raw and boiled Solanum tuberosum and Solanum phureja tubers. Journal of Food Composition and Analysis, Article in press.

Cartay, F. (2004). Difusión y Comercio de la yuca (Manihot esculenta) en Venezuela y en el mundo. Agroalimentaria , 18, 13 – 22. ISSN 1316 – 0354.

FAO (1993.) El maiz en la nutrición humana. Publicación N°TO395 ISBN 9253030135. Ed. Departamento de Agricultura.

FAO (2008). Año Internacional de la Papa. Nueva luz sobre un tesoro enterrado. Roma ISBN 978-92-5-306142-6.

FAO (2008-2009). PROYECTO FAO TCP/RLA/3107 (D) Desarrollo de Bases de Datos y Tablas de Composición de Alimentos de Argentina, Chile y Paraguay para fortalecer el comercio internacional y la protección de los consumidores.

FAO (2010a). Technical Workshop Report Biodiversity in Sustainable, Rome, 31 may-1 june. http://www.fao.org/ag/humannutrition/24994-064a7cf9328fbe211363424ba7796919a.pdf

FAO (2010b). Final Document International Scientific Symposium Biodiversity and Sustainable Diets, United Against Hungry, 3-5 Nov., FAO Headquarters, Rome.
http://www.fao.org/ag/humannutrition/23781-0e8d8dc364ee46865d5841c48976e9980.pdf

FAO (2010c). Foods and Nutrition Paper. 91 Fats and fatty acids in human nutrition. Report of an expert consultation, 10-14 November Geneve. FAO Agriculture Organization of the United Nations, Rome. ISBN 0254-4725.

FAOSTAT (2010). www.fao.org/corp/statistics/es/
Hoffmann-Ribani, R., Huber. L.S., Rodriguez-Amaya , D. (2009). Flavonols in fresh and processed Brazilian fruits. Journal of Food Composition and Analysis, 22, 263-268.

Jiménez, M.E., Rossi, A., Sammán, N. (2009a). Phenotypic, agronomic, nutritional characteristics of seven varieties of Andean potatoes Journal of Food Composition and Analysis, 22, 613-616.

Jiménez, M.E., Sammán, N. (2009b). Caracterización Nutricional de 6 Variedades de Oca (Oxalis tuberosa)". XV Congreso Latinoamericano de Nutrición, Noviembre de 2009, Santiago de Chile. Revista Chilena de Nutrición, 36, Supl. Nº 1, 674.

Kimura, M., Kobori, C.R., Rodriguez-Amaya, D., Nestel, P. (2007). Screening and HPLC methods for carotenoids in sweet potato, cassava and maize for plant breeding trials. Food Chemistry, 100, 1734–1746.

Lajolo, F.M., Menezez,W.E., De Vuono, M.C., Penteado, T.C.C., Filsetti, V.M., Lanfer, M. (2000). Tabela Brasileira de Composição de Alimentos, Ed. Universidade de São Paulo. Brasil. http://www.fcf.usp.br

Lucena, S.M. (2005). La América Precolombina. Primera edición. Editorial Amaya, Madrid, España, ISBN (10): 84-207-3420-9.

Masson, L. & Mella, M.A. (1985). Materias Grasas de Consumo Habitual y Potencial en Chile. Composición en Ácidos Grasos. Pp 23. Universidad de Chile. Santiago. Chile. Editorial Universitaria. Inscripción N° 60.867.

Masson, L., Camilo, C., González, K., Cáceres, A., Jorge, N., and Torija, ME. (2008a). New Sources of Oilseeds from Latin American Native Fruits". Natural Product Communication, 3, 357-362.

Masson, L., Camilo, C. y Torija, M.E., (2008b). Caracterización del Coquito de Palma Chilena, Grasas y Aceites, 59: 31-36.

Moenne-Locoz, D. (2008). Potencial antioxidante de Papas y Harina de Papas nativas de Chiloé. Tesis para optar al Título de Ingeniero en Alimentos. Facultad de Ingeniería, Ciencias y Administración, Departamento de Ingeniería Química, Universidad de la Frontera, Temuco, Chile.

Monge-Rojas, R., Campos,N.H., (2006). Tabla de Composición de Alimentos de Costa Rica, ácidos grasos. ISBN 9968-843-19-9. Ed. INCIENSA. San José, Costa Rica.
http://www.inciensa.sa.cr/files/refs/alimentos%20acidos grasos
Moreau, R.A., Singh, V., Powell, M.J., and Hicks, K.V., (2009). Corn Kernel Oil and Corn Fiber Oil. In R.A. Moreau & A. Kamal-Eldin (Eds) . Gourmet and Healthy-Promoting Specialty Oils. (First ed.) (pp.409-431). Urbana, Illinois, USA: AOCS Press.

Ospina, B. & Ceballos, H. (2002). La Yuca en el tercer Milenio. Cali, Colombia, Publicación CIAT N° 327, ISBN 958-694-043-8, Impreso en Colombia.

Rodriguez-Amaya, D., Kimura, M., Amaya-Farfan, J. (2008). Fontes Brasileiras de Carotenoides. Tabela Brasileira de Composicao de Carotenoides en Alimentos. Ministerio del Medio Ambiente, MMA, Ed. Brasilia, Brazil. IBNJ 978-85-7738-11

Schmidt.Hebbel, H., Pennachiotti, I., Masson, L., Mella, M.A. (1992). Tabla de Composición Química de Alimentos Chilenos. pp 16. (Octava Ed.) Universidad de Chile, Santiago, Chile. Imprenta Universitaria.

Tabla de Composición de Alimentos de Centro América. (2006). Ed. Instituto de Nutrición de Centro América y Panamá, INCAP, OPS, ciudad de Guatemala. Impreso. Guatemala, Centro América. http://www. Tabla de alimentos.org

Tablas de Composición de Alimentos de América Latina (2009 rev.). http://www.fao.org/infoods/tables_latin_es. stm

TACO. (2006). Tabela Brasileira de Composicao de Alimentos. Versao 2. Segunda Edicao. Campinas , SP. Nucleo de Estudios e pesquisas em Alimentacao-NEPA, Universidade Estadual de Campinas-UNICAMP. http//unicamp.br/nepa/taco/tabela.php

Tapia, M.E. (1997). Cultivos Andinos Sub explotados y su aporte a la Alimentación, Segunda Edición. FAO, Organización de las Naciones Unidas para la Agricultura y la Alimentación. Oficina Regional de la FAO para América Latina y el Caribe, Santiago, Chile.

Villalpando, S., Ramírez, I., Bernal, D., de la Cruz, V. (2007). Grasa, Dieta y Salud –Tablas de composición de ácidos grasos de alimentos frecuentes en la dieta mexicana. Instituto Nacional de Salud Pública, Cuernavaca, México, ISBN 978-970-9874-38-9.

Visioli, F., Bernaert, H., Corti, R., Ferri, C., Heptinstall, S., Molinari, E., Poli, A., Serafini, M., Smit, H.J., Vinson, J.A., Violi, F., and Paoletti, R. (2009). Chocolate, Lifestyle, and Health. Critical Reviews in Food Science and Nutrition, 49, 299-312.

CHAPTER 4
AN EXAMPLE OF A SUSTAINABLE DIET: THE MEDITERRANEAN DIET

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BIOCULTURAL DIVERSITY AND THE MEDITERRANEAN DIET

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Abstract
The Mediterranean diet constitutes a set of skills, knowledge, practices and traditions ranging from the landscape to the table, including the crops, harvesting, fishing, conservation, processing, preparation and, particularly, consumption of food. The Mediterranean diet is characterized by a nutritional model that has remained constant over time and space, consisting mainly of olive oil, cereals, fresh or dried fruit and vegetables, a moderate amount of fish, dairy and meat, and many condiments and spices, all accompanied by wine or infusions, always respecting the beliefs of each community. However, the Mediterranean diet encompasses more than just food. It promotes social interaction, since communal meals are the cornerstone of social customs and festive events. It has given rise to a considerable body of knowledge, songs, maxims, tales and legends. From 15 to 19 November 2010, the Fifth Session of the Intergovernmental Committee of the Convention will adopt the final decision over the nominations of new elements to be inscribed in the Representative List of the Intangible Cultural Heritage of Humanity.
Between these nominations, there will be the transnational nomination of the Mediterranean diet that already obtained in May 2010 a positive recommendation from the Subsidiary Body of the Committee. This decision of UNESCO will be a milestone in the path of the global recognition of the cultural values of food, agriculture and sustainable diet. The Mediterranean diet emphasizes the development of a relatively new concept: the bio-cultural diversity. This concept encompasses biological diversity at all its levels and cultural diversity in all its manifestations. Biocultural diversity is derived from the countless ways in which humans have interacted with their natural surroundings. Their co-evolution has generated local ecological knowledge and practices: a vital reservoir of experience, methods and skills that help different societies to manage their resources.

1. Not just biodiversity: towards the biocultural diversity

Since the 1980s of the twentieth century the need to protect and preserve biological diversity has been a global priority, becoming a pillar of the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 when it was agreed a clearer notion of "biodiversity", also developing an integration between biodiversity, climate change and desertification.
At the same time, however, it appeared clear that the biological diversity of ecosystems could not be protected without preserving cultural diversity in that same context at the same time. This awareness is clear from Article 8 of the Convention on Biological Diversity in which the primary objective of the States Parties to the Convention is not only to safeguard the biological diversity of living species, but to "respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities, which refer to traditional lifestyles relevant for the conservation and sustainable use of biological diversity".
Ten years after Rio, even though first in the scientific community, the concept of "biocultural diversity" was born (Maffi, 2001, 2005, 2010).
Integrating biological diversity and cultural diversity is becoming the mantra of the new century, the new commitment of States Parties and of the numerous United Nations conventions.
Since this concept it has been affirmed through different years, several legal instruments were established to protect on the one hand biological diversity in a strict sense (the CBD, for example, but also the FAO International Treaty on Plant Genetic Resources for Food Agriculture in 2001 and the MAB Programme – UNESCO Man and Biosphere), on the other hand cultural diversity (UNESCO, first, with the conventions on cultural heritage and natural material of 1972, the intangible cultural heritage of 2003 on Cultural Diversity of 2005).
Over the years, the need to integrate the various in-

ternational legal instruments of protection in order to preserve the biological and cultural diversity (i.e. the biocultural diversity) emerged.
"The inextricable link between biological and cultural diversity" is for the first time spelled out in the Declaration of Belem, which was adopted by the First International Congress of Ethnobiology in 1988. The discussion around this issue became even more intense at the end of the last century. In 2001, UNESCO unanimously adopted in Paris, during the 31st Session of the General Conference, the Universal Declaration on Cultural Diversity, which, in addition to affirming the fundamental human rights in terms of intellectual, moral and spiritual integration within the concept of cultural diversity, gives some ideas and concepts related to biological diversity.
In 2005, for the first time, the Tokyo Declaration was adopted with the aim of creating a link between cultural diversity of religious or sacred sites protected by UNESCO and the biological richness of those contexts.

In June 2010, in Montreal, many governments, NGOs and associations participated in the International Conference on Cultural and Biological Diversity for Development organized by UNESCO and the CBD, and a Final Declaration was adopted which, after recognizing the need to develop actions so as to preserve biological diversity and cultural diversity, established a ten-year work programme that will, *inter alia*, create a link between the different legal instruments. This declaration (which is actually much more than just a statement) was approved at COP 10 of the Convention on Biological Diversity.

2. A new challenge for world legislators: preserving the biocultural diversity

Speaking of biocultural diversity instead of biodiversity is not just a matter of terminology. It means, in fact, being aware of the close correlation between the loss of cultural and linguistic diversity and loss of biological and genetic diversity, and vice versa (Harmon, 2002). This implies, for anyone who wants to develop a legal discourse, perhaps in order to introduce measures to safeguard or enhance, learning to think in interdisciplinary terms.
This same approach should be used to define the concept of biocultural diversity which includes "diversity of life in all its forms: biological, cultural and linguistic diversity, inter- (and probably co-evolved) within a socio-ecological complex adaptive system".
In order to safeguard the biocultural diversity it is therefore necessary to integrate knowledge from different fields: anthropology, linguistics, ethnobiology, etnoecology, biology, agronomy, ecology and many others (Maffi and Woodley, 2010). But we must, above all, realize that "the diversity of life is not constituted only by the diversity of plant and animal species, habitats and ecosystems on the planet, but also by the diversity of cultures and human languages, these differences do not develop in separate and parallel worlds, but are different manifestations of a single whole and complex relationships between diversity have been developed over time through the cumulative effects of global mutual adaptation – probably coevolutionary nature – between human beings and the local environment" (Maffi, 2010, p. 298).
The starting point that the lawyer must consider is that human beings do not live in an abstract and isolated context but they always have a close relationship with the environment that surrounded them. This environment has always been changed in order to respond to the needs of the human beings; at the same time, they become influenced and shaped by the same environment (Posey, 1999): "This implies that the organization, the vitality and this resilience of human communities are closely linked organization, the vitality and resilience of ecosystems" (Maffi, 2010, p. 298).
In industrialized societies the perception of identity linked to the bond between humans and their environment is getting lost; in indigenous societies, by contrast, the link between the languages, traditions, land and ecosystem is still very strong (Blythe and McKenna Brown, 2004).
Among others, linguistic diversity is, therefore, the representative indicator of cultural diversity (Stepp

et al., 2003). According to data provided by Terralingua, in the world there are from 6 000 to 7 000 different languages, of which 95 percent is the mother tongue of less than one million people. However, linguistic diversity cannot be regarded as the only benchmark. Other factors that relate to the cultural life of a community, such as traditions, folk festivals, events, rituals, social practices, all that intangible cultural heritage referred to in the 2003 UNESCO Convention on World Heritage Intangible Heritage need to be analysed.

3. The world of agriculture and biocultural diversity

The close relationship between biological diversity and cultural diversity is evident especially if you look at global food trends. In other words this relationship can be emphasized as the c.d. agrobiodiversity that can be considered, in itself, an effective index for understanding both the causes and consequences of the loss of biocultural diversity.

According to FAO (1998 data) the plant species used for food production are about 7 000, but today only 30 are under cultivation, and of these, rice, wheat and corn alone cover 50 percent of needs World Food. The loss or abandonment of these crops can be explained by several factors, primarily cultural, in a globalized world, the food seems to be the main victim of the "trend" diet, and it is not just a matter of "appeal". The disappearance of some traditional food is closely related to non-transmission, from parents to children, of the methods of production or storage or handling of food. With a further consequence: the loss of knowledge related to the cultivation of the plant species, which is the prelude to their ultimate demise. The available data are alarming in this respect: just after the Second World War, China, for example, had 10 000 cultivated varieties of wheat, in the 1970s just under 1 000, today about 200. In Mexico, over the past fifty years, 80% of maize varieties, the product symbol of Mexican cuisine, have been lost. In the United States, 95% of the varieties of cabbage, 86% of apples, peas 94%, 81% of tomatoes have disappeared at the same time (Buiatti, 2007, p. 109).

4. The role of UNESCO: 2003 Convention and the Mediterranean diet

UNESCO stands internationally as the only global organization that within its conventions and programmes embraces the concepts of nature and culture, biological and genetic diversity and cultural and linguistic diversity.

Cultural diversity, as it has been mentioned, was, in fact, subject to specific conventions adopted by UNESCO: the Convention on Cultural Heritage in 1972, the Convention on Intangible Cultural Heritage of 2003, the Convention on Cultural Diversity of 2005. Even before the adoption of these international conventions, within UNESCO in 1971 was launched, the Programme MAB – Man and Biosphere, which immediately turned his attention to the protection of biodiversity in the traditional sense and conservation and strategic management of biodiversity.

Founded in the wake of the UNESCO Declaration of Principles of International Cultural Cooperation in 1966, the need to identify and ensure protection measures for the so-called "Intangible Heritage" in its various cultural forms and in the interaction between human activity and both physical and social environment, was clear since 1972, the adoption of the best known UNESCO Convention for the Protection of Cultural Heritage and World Heritage.

Since then, concepts such as folklore, oral expressions, traditional techniques of land management and artistic representations of identity and creativity have been revised several times over several sessions until the adoption, during the 32nd General Conference in 2003, of an ad hoc instrument, the Convention for the Safeguarding of the Intangible Cultural Heritage, signed on 17 October 2003.

The intangible heritage, according to the list provided by Article 2, para. 2, is detectable in 5 areas (oral traditions and expressions, including language as a vehicle of intangible cultural heritage, performing arts, social practices, rituals and festive events; the knowledge and practices concerning nature and universe, traditional craftsmanship). This list does not appear, however, mandatory in nature; especially because of the difficulty of assigning precise classification schemes to the concept of culture, but also because of the intersectoral nature of some oral traditions also when the practices are integrated with food as an integrated system of social relations and shared meanings. Practices related to food are in fact connected to the oral traditions and expressions, to performing arts, to social practices, to some rituals and festivals, to knowledge and practices concerning nature and to the know-how linked to traditional crafts.

Following this approach, in November 2010 on the occasion of the Fifth Session of the Intergovernmental Committee of the 2003 Convention, elements concerning food practices, including the Mediterranean diet were entered for the first time in the Representative List.

In 2008, four countries, namely Italy, Spain, Greece and Morocco, decided to share their own cultural heritage represented by a common way of life and to begin the path of recognizing it as part of the UNESCO Intangible Cultural Heritage of Humanity. The Mediterranean diet constitutes a set of skills, knowledge, practices and traditions ranging from the landscape to the table, including the crops, harvesting, fishing, conservation, processing, preparation and, particularly, consumption of food. The Mediterranean diet is characterized by a nutritional model that has remained constant over time and space, consisting mainly of olive oil, cereals, fresh or dried fruit and vegetables, a moderate amount of fish, dairy and meat, and many condiments and spices, all accompanied by wine or infusions, always respecting the beliefs of each community. However, the Mediterranean diet (from the Greek "diaita", way of life) encompasses more than just food. It promotes social interaction, since communal meals are the cornerstone of social customs and festive events. It has given rise to a considerable body of knowledge, songs, maxims, tales and legends. The system is rooted in respect for the territory and biodiversity, and ensures the conservation and development of traditional activities and crafts linked to fishing and farming in the Mediterranean communities.

The decision to inscribe the Mediterranean Diet in the UNESCO list is a milestone in the path of the global recognition of the cultural values of food, agriculture and sustainable diet. The Mediterranean diet is a unique lifestyle of a particular territory and its sustainability is recognized as a common cultural heritage of Mediterranean communities.

The Mediterranean diet, as an example of sustainable diet, makes clear and evident the link between cultural and biological components, between the environment and human sustainable activities such as traditional agriculture and fishery. The Mediterranean diet emphasizes the development of a relatively new concept: biocultural diversity. This concept encompasses biological diversity at all its levels and cultural diversity in all its manifestations. Biocultural diversity is derived from the countless ways in which humans have interacted with their natural surroundings. Their co-evolution has generated local ecological knowledge and practices: a vital reservoir of experience, methods and skills that help different societies to manage their resources.

This is an example of how, thanks to the so-called "UNESCO system" (Petrillo, Di Bella, Di Palo, 2012), thereby indicating that set of conventions and programmes that protect the tangible and intangible cultural diversity and biological diversity, and to the persistence of local populations, we may now be able to protect and preserve an area in the cultural and biological diversity, in Italy this area is the Cilento.

The National Park of Cilento and Vallo di Diano, in fact, was inscribed in 1997 to UNESCO's World Network of biosphere reserves recognized by the MAB Programme: it is, therefore, recognized as a unique ecosystem, a high concentration of biodiversity. In addition, since 1998 it has been inscribed in the UNESCO World Heritage list being considered by UNESCO as a unique cultural landscape, the result of centuries of human labour and processing of natural resources. In addition, since 2010, the Cilento is one of the four communities identified by the nomination of the Mediterranean diet Intangible Heritage of Humanity: UNESCO has recognized Cilento has handed down traditions and expressions, ancient food practices, cultural diversity, unique and preserved over the centuries. Cilento, thus, represents a unique identification of the concept of biocultural diversity: in this context, in fact, the original characteristics of ecosystems and the knowledge and traditions of local people and their artefacts, are the witnesses of the inextricable link between culture and nature, that go together here, in a close co-evolution.

5. For a new awareness: it is useless to protect biodiversity without preserving cultural diversity

From this picture it is clear that the challenge that the legislators all over the world are facing is to introduce mechanisms to protect, preserve and enhance the set of biological and cultural diversity represented in a community. Unique approaches to this subject will, in the long term, avoid a further loss of biodiversity. In the world, where the beating of a butterfly in China produces an economic tsunami in the United States, it is no longer possible to think and act locally and compartmentalized. We could also start from a fact: in the last 20 years the world has lost so much of its richness in genetic, biological and cultural that if we do not do something to counter this loss in a coordinated and comprehensive way, in another two decades we will be happily doomed to extinction (UNEP, 2010). For example: in 2100 will disappear about 80 percent of the languages spoken today.

But then, who "governs" biocultural diversity? Who has the authority to act to redress the loss in a maybe too much polycentric institutional context too?

The challenge to counter the loss of biocultural diversity collides with the increasingly federal structure of the states, so that we can draw a curve that shows how more fragmented institutional contexts (or "exploded" or "polycentric"), the lower capacity for action to tackle environmental and cultural damage.

The real challenge of the legislative branch is primarily a challenge to themselves, to challenge themsleves and deal with different sciences, trying to find a common language. It is a legal challenge to the traditional object of study, because now lawyers should try to analyse it in a diachronic and interdisciplinary way individual rules and then put them in a different context.

References

Blythe, J., McKenna Brown, R. (2003). Making the Links: Language, Identity and the Land. Papers from the 7th Foundation for Endangered Languages conference, Bath: Foundation for Endangered Languages, Broome, Western Australia.

Harmon, D. (2002). In Light of Our Differences: How Diversity in Nature and Culture Makes Us Human. Washington: Smithsonian Institution Press.

Maffi, L. Woodley, E. (2010). Biocultural diversity conservation: a global sourcebook. London: Earthscan.

Maffi, L. (2001). On biocultural diversity: linking language, knowledge, and the environment. Washington: Smithsonian Institution Press.

Maffi, L. (2005). Linguistic, Cultural and Biological Diversity. In The annual review of anthropology, 34, 599-617.

Maffi, L. (2010). Language: A Resource for Nature. Nature and Resources. In The UNESCO Journal on the Environment and Natural Resources Research, 34, Paris, 12-21.

Petrillo P. L., Di Bella O., Di Palo N. (2012), La convenzione UNESCO per il patrimonio mondiale e la valorizzazione dei paesaggi rurali, ed. G. M. Golinelli "Patrimonio culturale e creazione di valore", CEDAM, Roma

Posey, D. (1999). Cultural and spiritual values of biodiversity. A complementary contribution to the global biodiversity assessment. In Cultural and spiritual values of biodiversity, ed. D.A. Posey, UNEP and Intermediate Technology Publications, London, 1–19.

Stepp, J.R. et al. (2003). Ethnobiology and biocultural diversity: proceedings of the Seventh International Congress of Ethnobiology. International Society of Ethnobiology, Athens: University of Georgia Press.

UNEP (2010). Rapporto sullo stato dell'Ambiente. United Nations Environment Programme.

SUSTAINABILITY OF THE FOOD CHAIN FROM FIELD TO PLATE: THE CASE OF THE MEDITERRANEAN DIET

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Abstract
The Mediterranean diet is considered as a paragon among the world's diets. The reference is the diet of Crete in the late 1960s. Is it provided sustainable?

Various authors have commented on the design of sustainable food. Some emphasize healthy food and alternative agriculture, while others focus on the link between health and welfare, or environmental practices on consumers. For us sustainable food is the one that combines the protection of nutrients, environmental conservation, community development through social aspects.

The traditional Mediterranean diet may be considered as sustainable in part because of (i) a great diversity that ensures food nutritional quality of diet and biodiversity, (ii) a variety of food practices and food preparation techniques, (iii) main foodstuffs demonstrated as beneficial to health as olive oil, fish, fruits and vegetable, pulses, fermented milk, spices, (iv) a strong commitment to culture and traditions, (v) a respect for human nature and seasonality, (vi) a diversity of landscapes that contribute to the well-being, (vii) a diet with low environmental impact due to low consumption of animal products. However, trends in plant breeding on an economic base, intensive modes of production and greenhouse production, higher consumption of meat, industrialization of food, endanger the sustainability of food systems. No analysis of social impact has been achieved. We cannot conclude on this aspect of sustainability, nor on the environmental impact of the food chain.

In conclusion, the Mediterranean diet has numerous virtues. We must ensure that modernity and globalization do not alter its characteristics of sustainability.

Introduction
The Mediterranean diet has enjoyed a high reputation over many years, both for its nutritional quality and its health benefits. The traditional Mediterranean diet of the 1960s is considered a model of nutritional benefits (Padilla, 2008). Its multifunctional nature, encompassing the entire range of ecological, nutritional, economic and social functions, puts food at the heart of the concept of sustainable development.

Sustainable food is a concept that has been developed as a key factor to reduce negative externalities of the global food supply chain. Beyond the preservation of the environment, sustainable food includes also moral and health aspects of eating (ethic and nutrition), satisfaction of consumer expectations, and improved product accessibility at geographic and economic level. Faced with fossil energy exhaustion, soil limited capacity, ecosystem degradation, climate change and global warming, unbalanced diets and population increase, we wonder if the Mediterranean current food system can be considered as sustainable. Is the Mediterranean diet consistent with sustainable development? The aims of this paper are (i) to characterize the different aspects of sustainability of the traditional Mediterranean diet (ii) to analyse what are the principal hot spots of food systems today in the Mediterranean area with regard to sustainability.

Material and methods
The definitions of sustainable diets show that they affect various dimensions (agricultural, food, nutritional, environmental, social, cultural, economic) that interact with one another, either inseparably or separately and distinctly. From this point of view, the Mediterranean is the area where more than any other many issues (biodiversity loss, soil erosion, water scarcity etc.) directly or indirectly related to Mediterranean food consumption patterns should be addressed. We have summarized the criteria of sustainable food in Table 1. It is a combination of preservation of the environment, nutrition, and development of the local territory by social and economic aspects all along the food chain, from agriculture to the consumer.

	Environment	Nutrition	Economic	Socio-cultural
Agriculture	Follow sustainable agricultural practices Enhance resilience of production systems Deploy and maintain diversity	Promote diverse food Produce nutritionally dense product	Deploy affordable cultivation practices Promote self reliance through local produce	Maintain traditional agriculture practices and promote local varieties
Food Production	Reduce impact of production, processing, commercialization	Preserve nutrients throughout the food chain	Strengthen local food systems Produce affordable food	Produce culturally acceptable foood
Consumption	Reduce the environmental impact of feeding practices	Promote dietary diversity, food balance and seasonality	Promote access to dietary diversity	Safeguard food traditions and culture Meet local preference & taste

Table 1. The grid of sustainable food system.

From our previous works and experience of the Mediterranean area, we will develop our thinking about each element of sustainability.

Results and discussion

I. Is the traditional Mediterranean food chain linked with the traditional diet sustainable?

Environment: the uniqueness of the Mediterranean area, one of 25 "hot spots" of biodiversity on the planet

The importance of the Mediterranean area as regards crop diversity can be judged by the fact that about one-third of the foodstuff used by humankind comes from the Mediterranean climatic region (Harlan, 1995). The Mediterranean basin was one of the eight centres of cultivated plant origin and diversity identified by Vavilov (1951). He listed over 80 main crops and the most important of these are cereals, pulses, fruit trees and vegetables. There were also many herbs, spice-producing plants, horticultural crops, and ornamentals (Heywood, 1998). Several sociopolitical, agroclimatic, ecological and genetic factors have contributed to this remarkable crop diversity in the Mediterranean (Jana, 1995).

Approximately 30 000 plant species occur, and more than 13 000 species are endemic to the hot spot; yet, many more are being discovered every year (Plantlife International, 2010). The Mediterranean Basin is 1.6% of world land with 10% of known flowering plants and 18.4% of mammal species; 0.7% of the world ocean, with 8–9% of known marine organisms (Sundseth, 2009). The hot spot has roughly the same plant diversity as all of tropical Africa, albeit in a surface area one-fourth the size of sub-Saharan Africa (CEPF, 2010).

There are more plant species in the European Mediterranean region than all the other European bio-geographical regions combined. The Mediterranean forests are diverse and harbour up to 100 different tree species. In the Mediterranean Basin there is huge topographic, climatic and geographic variability giving rise to an astounding array of species and habitat diversity.

A diverse landscape

A large diversity of landscapes was shaped by the practices of agriculture and livestock. This contributes to well-being and environmental protection. Cereal, fruit trees, olive groves, vineyards, horticulture, gardening, were cultivated on small perimeters. Agricultural lands and grasslands occupy 40 percent of the Mediterranean region and vary between large intensive olive or citrus groves to more mixed farming systems (Elloumi and Jouve, 2010). The low intensity and localized nature of thousands of years of subsistence farming activities has had a profound effect on the landscape, creating a complex mosaic of alternating semi-natural habitats rich in wildlife. Vineyards and ancient olive groves are also still a characteristic feature of the Mediterranean landscape. On flatter land and in the plains various forms of sustainable agro-sylvo-pastoral farming systems have evolved that make best use of natural resources (Sundseth, 2009). Ranching is also practiced on the land fallow or wasteland or vast semi-desert lands.

Agriculture practices preserving the environment?

We see the continuation of small-scale family farming (17 million family farms with two-thirds or three-quarters less than 5 ha in Turkey, Morocco, Italy, Greece, for example (Elloumi and Jouve, 2010). They practise traditional agriculture-intensive labour and low use of capital. This agriculture is likely to solve the food crisis, according to Olivier de Schutter, Rapporteur on the right to Food at the UN. It is also an agriculture that preserves the earth, by increasing local productivity, reducing rural poverty, contributing to improved nutrition and facilitating adaptation to climate change.

The richness of Mediterranean agriculture is its diversity of cropping patterns. We distinguish five forms of agriculture in the Mediterranean, especially on the outskirts of towns: (1) An entrepreneurial agriculture, innovative, with high added value. It is an innovative farming vegetable speculative, capital intensive, growing thanks to the availability of capital in the current conditions. (2) An opportunistic agriculture in extension due to the constraints of access to land. It is practiced on large farms consisting of clusters of plots, left short-term leases, usually oral. (3) Family farms in the suburban area specialized in local productions to be sold directly in farmers markets. (4) Agriculture need, practiced by the rural exodus from the city and recently installed, because of economic crises; it tends to perpetuate. (5) Pleasure agriculture: the traditional Mediterranean cultivation has an interest in landscape and identity, such as vineyards and olive trees; they are renewed in European countries where they receive aid from the CAP. The aim of policies related to territory quality (AOC) is to ensure the sustainability of these local productions (Jouve and Padilla, 2007).

Another aspect of land preservation is the commitment to organic farming. Mediterranean organic agriculture is growing, but covers a very small percentage of agricultural land: 4.5% in Italy, between 2 and 3% in Spain and Greece, 6.2% in Slovenia, less than 2% in France, 1.5% in Tunisia and less than 1% in other countries (Plan Bleu, 2006). If organic agriculture does not meet market demand in the North, it does not have a local market in the South. This greatly limits its expansion.

The environmental impact of the diet

Duchin (2005), who studied diets from multiple points of view of sustainability, showed that a Mediterranean diet, which consists mainly of plant-origin foods but not excluding a small proportion of meat and other animal products, is closer to public health recommendations issued by the World Health Organization and has a lower environmental effect than the current average United States diet.

If, for reasons of public health, the plant-based Mediterranean diet is adopted throughout the United States, not only major structural changes would be needed in agriculture, but the farmland dedicated to food would decrease. Indeed, Duchin argues that the typical Mediterranean diet differs from the current dietary recommendations in the United States by including a much lower meat consumption. This choice would also benefit the environment and that food choice is all the more commendable that the environment would benefit too. Among the various diets tested by Duchin, in a global economy model that incorporates Life Cycle Analysis of 30 foods, plant-dominated diet type emerges as the Mediterranean diet, can meet both nutritional and environmental requirements, and for a growing world population while reducing the pressure of food and agricultural systems on the environment.

Nutrition sustainability: few animal products in the diet

The east Mediterranean diet of the early 1960s has interesting qualities for the development of options to create more sustainable, healthy diets. The environmental impacts of animal production vary with the method of production (e.g. extensive grazing, grazing-based production) (MFAF-DK, 2010).

Meat production has a higher environmental impact than fruit and vegetables production. The global livestock sector contributes about 40 percent to global agricultural output. Meat and dairy animals now account for about 20 percent of all terrestrial animal biomass (Steinfeld *et al.*, 2006). According to the Livestock, Environment and Development initiative, the livestock industry is one of the largest contributors to environmental degradation, at local and global scale, contributing to deforestation, air and water pollution, land degradation, loss of topsoil, climate change, the overuse of resources including oil and water, and loss of biodiversity. The use of large industrial monoculture, common for feed crops (e.g. corn and soy), is highly damaging to ecosystems. The initiative concluded that the livestock sector emerges as one of the most significant contributors to the most serious environmental problems. A person existing chiefly on animal protein requires ten times more land to provide adequate food than someone living on vegetable sources of protein (MFAF-DK, 2010) which means a much higher ecological footprint

Type of Food	Area required
Vegetarian food	500 m^2
Dominant vegetarian food	700 m^2
Western diet	4 000 m^2
Mainly meat diet	7 000 m^2

Table 2. Ecological Footprint of different food diets.
Source: FAO.

The Mediterranean variety is major. It helps to meet diverse nutritional needs and to limit the environmental impact

There is growing evidence of the impact of diet on health, including increased risk of obesity, cardiovascular diseases and cancers, and also of its role as a social indicator (Reddy *et al.*, 2009; Hawkesworth *et al.*, 2010). Dietary diversity that characterizes the Mediterranean diet explains the disease prevention related to diet. A study of the index of food variety in several countries has shown that France has a very high rate (90%) compared to the United States (33%). In Morocco, the dietary diversity score was 10.2 for ages 12 to 16 years (Aboussaleh and Ahami, 2009). Other surveys in 2006 for adults (Anzid *et al.*, 2009) also showed high levels of dietary diversity in urban areas only.

Beyond the diversity in terms of different categories of food and in terms of different foods within a category, it should be noted the peculiarity of the Mediterranean diet for the variety of flavours: acid, sweet and sour, salty-sweet, bitter, pungent. The preparation techniques are also very diverse: flavoured, breaded, chopped, into batter, stuffed pastry, salads; the techniques of preservation also: sun-drying, salting, fermentation, vinegar, oil, candied (we find all these technical approaches in the Mune in Lebanon). The diversity can be found also in cooking techniques: boil, simmer, roast, broil, fry, steam. People eat structured meals taken in a friendly way. Families and friends eat together tapas in Spain, tramessi in Italy, kemia in Tunisia, meze in Lebanon, mézélik in Turkey.

The recommended Mediterranean food pyramid expresses such diversity (Figure 1).

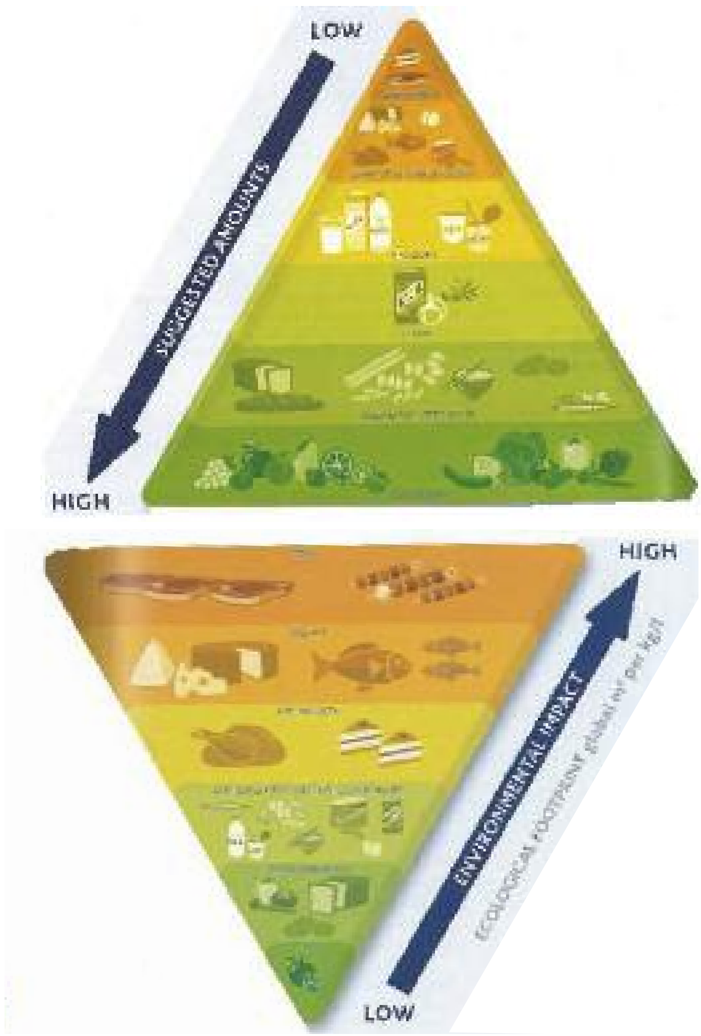

Figure 1. The double pyramid.
Source: Barilla Center, 2010

It not only offers considerable health benefits to individuals but also respects the environment and has less impact. Barilla Center for Food and Nutrition demonstrated that the foods that are recommended to be consumed more frequently, are also those with minor environmental impacts (per kg). In other words, the inverted environmental food pyramid illustrates how the most environmentally-friendly foods also tend to be the healthiest (Barilla Center, 2010). As a matter of fact, the various food groups can be evaluated in terms of their environmental impact. Reclassifying foods no longer in terms of their positive impact on health, but on the basis of their negative effect on the environment, produces an upside-down pyramid which shows the foods with greater environmental impact on the top and those with lower impact on the bottom. When this new environmental pyramid is brought alongside the food pyramid, it creates a food-environmental pyramid called the “Double Pyramid”. It shows that foods with higher recommended consumption levels are also the ones with lower environmental impact. This unified model illustrates the connection between two different but highly relevant goals: health and environmental protection. In other words, it shows that if the diet suggested in the traditional food pyramid is followed, not only do people live better (longer and healthier), but there is a decidedly lesser impact – or better, footprint on the environment.

Respect of human nature

Mediterranean people have benefited from the influence of Hippocras about the categorization of food and eating behaviours: hot, cold, wet or dry properties. There is an adaptation to natural conditions in respect of the seasons and a necessary balance among different kinds of products according to the seasons, metabolism and health of individuals.

Social and economy sustainability: strengthen local food systems

Historically, in Europe, the Mediterranean countries have the largest number of initiatives of geographical indications (GI). Locally, they are indicative of a strong connection to the land, the notoriety, the history and the quality of the product. Nearly 80 percent of GIs in the European Union are from Mediterranean countries. France represents alone 20 percent followed by Italy, Portugal, Greece and Spain. In southern countries, this process is beginning in Morocco, Tunisia, Lebanon.

In Mediterranean countries, there is a strong attachment to traditions and culture and food is an integral aspect of human culture. The culinary tradition is still transmitted from mother to daughter, although the cookingprocess is often simplified. Festive occasions around food are common: celebrations, religious rituals. Modern life leads to strong ambivalent practices between acculturation and transmission of a cultural identity. To preserve the Mediterranean food culture, UNESCO has recently recognized the Mediterranean diet as an intangible heritage of humanity (2010) in four countries: Spain, Greece, Italy and Morocco. It will be included in a transnational Mediterranean inventory in preparation.

II. The principal hot spots of food systems today

The risks on biodiversity

Biodiversity is threatened because pollution, overexploitation, natural disasters, invasive alien species, tourism, intensive agriculture. The change in eating habits combined with the pursuit of profitable varieties led to the abandonment of local varieties and cultural degradation of specific products. There is a globalization of the food market with absurd transport costs, an organization of the food chain in function of economic considerations, without taking into account the environmental impact: 30 percent of greenhouse gas emissions are linked to the food in France. Specialization in agriculture and the changing patterns of farming techniques deplete biodiversity and have a negative impact on greenhouse gas emissions. For instance, there are more and more greenhouses in the south of Spain: 40 000 ha of vegetables in Almería, 7 500 ha of strawberry in Huelva. A majority of the workforce is composed of illegal immigrants.

We are in an era of unprecedented threats to biodiversity: 15 out of 24 ecosystems are assessed to be in decline (Steinfeld *et al.*, 2006). The genetic diversification of food crops and animal breeds is diminishing rapidly. At the beginning of the twenty-first century it was estimated that only 10 percent of the variety of crops that had been cultivated in the past were still being farmed, with many local varieties being replaced by a small number of improved non-native varieties (Millstone and Lang, 2008). Only about 30 crop species provide 95 percent of food energy in the world while 7 000 species, that are partly or fully domesticated, have been known to be used in food including many of the so-called underutilized, neglected or minor crops (Williams and Haq, 2002). Humanity depends on ecosystems and their life-sustaining goods and services.

WWF (World Wide Fund for Nature) has listed 32 ecoregions in the Mediterranean hot spot. There are three broad vegetation types: maquis, forests and garrigue (CEPF, 2010). Nowadays, the most widespread vegetation type is the maquis. Many of the endemic and restricted-range plants depend on this habitat; thus, several species are threatened (Tucker and Evans, 1997).

However, whilst small-scale farming is still practised in many parts of the region, the last 50 years have seen a massive change in agricultural practices across large parts of the Mediterranean. Ancient vineyards, orchards and olive groves have been ripped out to make way for industrial-scale fruit or olive plantations and mixed rotational farming has been replaced by intensive monocultures. This has not only caused the loss of wildlife-rich habitats but has also had a major socio-economic impact on large parts of the region as many small-scale farmers have been forced to abandon their land to go and search for jobs elsewhere.

Farming systems

The global changes affecting the Mediterranean region have effects on farming systems and processing of food derived from them. Overall, we can expect a widening of the social and economic divide between industry and family agriculture, namely in the South, because the region is highly dependent on of agricultural imports and therefore subject to the hazards of world agricultural production and its "crisis"; an integration of food to better control price volatility of primary production, while promoting the

internationalization of production.
These trends are consistent with the reconstruction of territories: concentration of population in urban and coastal areas; concentration of large farms, competition for use of space between rural and urban areas, and risk of a progressive disqualification of small farming. These changes are associated with the degradation of agro-ecosystems due to climate change, to intensifying production and a devaluation of traditional knowledge, with consequences: a recurring emergence of diseases of various origins, increasing pressure of invasive species, and degradation of biodiversity; stress on crop yields associated with an increase in agricultural water demand coupled with lower ground and underground flows, tensions to share water between uses. In this context of strong pressure on resources (water, land), and increased concentration of population, and environmental degradation, the major health crises, affecting animals or plants, are likely (international trade increasingly important to promote migration of invasive species and pathogens).

Use of water

Modern farming practices through their high demand for pesticides, fertilizers and irrigation water also put excessive pressure on the environment. More than 26 million ha of farmland are now under irrigation in the Mediterranean Basin and in some areas up to 80 percent of the available water is used for irrigation. The exceptionally rapid growth in tourism and urban development in coastal areas combined with the abandonment of small-scale farming practices puts immense pressure on the Mediterranean region's rich biodiversity (Sundseth, 2009).
The Mediterranean population is particularly affected by water scarcity: it represents 60 percent of the population of water-scarce countries in the world with less than 1 000 m^3/inhabitant/year (PlanBlue, 2006). Water demand doubled during the second half of the twentieth century to reach 280 billion m^3 per year for all riparian countries: 64% is for agriculture (82% in southern countries), 13% for tourism. Moreover, the complexity of the food chain increases the use of virtual water. In the Mediterranean region, water resources are limited, fragile and unevenly distributed over space and time where southern rim countries are endowed with only 13 percent of the total resources (Plan Blue, 2006). According to the projections of the Plan Blue baseline scenario and compared to the year 2000, water demands may increase by a further 15 percent by 2025, especially in the southern and eastern countries where an increase of 25 percent is expected. Furthermore, Mariotti *et al.* (2008) predicted by 2070–2099 an average decrease of 20 percent in land surface water availability, with a decrease in soil moisture and river runoff, and a 24 percent increase in the loss of fresh water over the Mediterranean due to precipitation reduction and warming-enhanced evaporation. Thus, improving the water demand management, water saving and rational water use, especially for agriculture, is of paramount importance in the Mediterranean region.

A surge of supermarkets

According to expert estimates, the agro-industrial service model, characterized by mass consumption of industrialized products driven by hyper- and supermarkets, may locate in any region where the average revenue per capita is above US $ 5 000 per head. In 2008, in all Mediterranean countries this limit was reached except in Morocco. For some ten years Mediterranean countries have been facing the development of modern food distribution. If it holds 75 percent of the food market in the north, it remains modest in the south with 5–10 percent, but is growing strongly. In Egypt, it is estimated that around 90–95 percent of the food outlets can be categorized as small grocery stores. The modern retail food service has tripled in five years. In Morocco, like in Tunisia, the modern distribution has duplicated the number of establishments in the last five years. We can count 32 Auchan /Marjane, Metro, Label'Vie, Casino/Asmak Assalam (Chaabi group) in Morocco; 1 Carrefour, 44 super Champion et Bonprix, 1 Géant Casino, 39

Monoprix et Touta, 44 super Magasin Général in Tunisia; and only 1 Carrefour, Blanky/Promy, Cevital in Algéria.
An indicator of each country potential for retail developments is provided by AT Kearney. They classify every year the 30 more promising emerging countries, according to an index based on a set of 25 variables including economic and political risk, retail market attractiveness, retail saturation levels, modern retailing sales area and sales growth. According to the classification for 2010, there were 10 Mediterranean countries ranked in the following places: Tunisia (11), Albania (12), Egypt (13), Morocco (15), Turkey (18), Bulgaria (19), Macedonia (20), Algeria (21), Romania (28) and Bosnia-Herzegovina (29). The problem is that this method of distribution extends distribution channels, massive purchases and sells a wide range of products highly industrialized and not always conducive to health. Thus we are seeing the explosion of soft drinks consumed at any time of the day.

A Food Quality Index of food in regression

Based on the recommendations of the National Research Council, the American Health Association, and the latest proposals of the joint committee of FAO / WHO (2003), we see that the Food Quality Index is decreasing in the main Mediterranean countries.

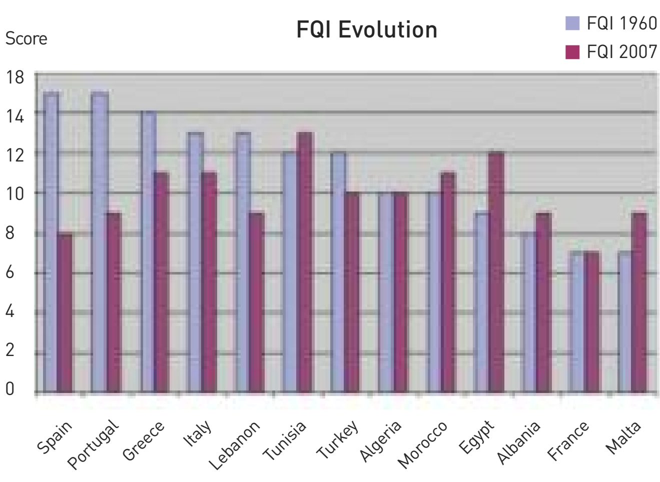

Figure 2. FQI evolution within the Mediterranean countries (1960-2007).
Source: Based on FAO data.

Major concerns relate to the aggravation of saturated fat (meat, dairy and industrial foods), a very sharp increase in sugars (sodas, cookies, desserts), a reduced consumption of starches (bread, potatoes), and micronutrient deficiencies.
The mirror of the new eating behaviours is the increasing overweight and obesity. The main causes are: the lifestyle, the type and frequency of physical activity, the type and quality of food consumed and time spent on food related activities (shopping, cooking, etc.).

A negative balance of the total ecological footprint in the Mediterranean region

With modern diets and food consumption patterns there is a trend to have a greater flow of food commodities over long distances, and highly processed and packaged foods that contribute to increased emissions of greenhouse gases and non-renewable resources depletion. Alteration of the ecosystem occurs if an area's ecological footprint exceeds its biocapacity. Balance of the total ecological footprint in the Mediterranean is shown in Figure 4 based on data of the global footprint network for the year 2007. The results put in evidence an ecological deficit in the Mediterranean region and an alteration of the ecosystem is therefore occurring. The ecological deficit is more pronounced in the Balkans and northern Mediterranean even if they have a higher biocapacity with respect to North Africa and the Near East.

Conclusions

The grid of sustainable diet: what should be done?

For the immediate future, we recommend a better synergy between environmental and health education to obtain agreement for a dietary change for the general public. A lot of researchers explained the health benefits that a plant-based diet would have on health and environment, and this knowledge could be translated into information campaigns. Further research is needed to understand barriers and why changes in diets have not been a main issue on the climate agenda until now. It is there-

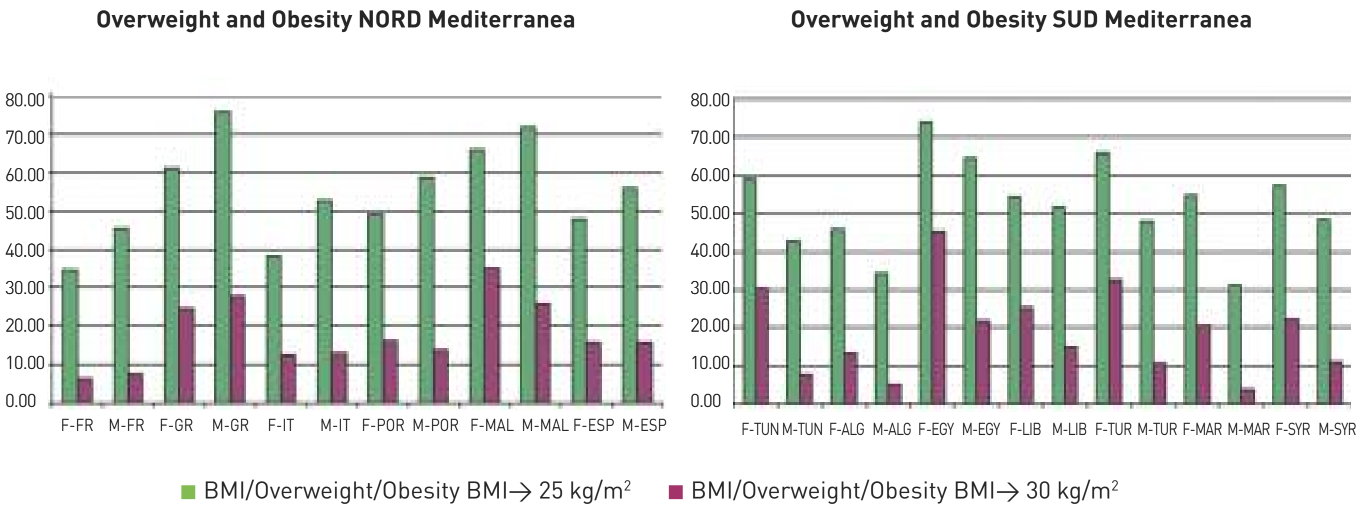

Figure 3. Overweight and obesity in Mediterranean countries.
Source: WHO, 2009.

fore necessary to act urgently to implement a strategy that promotes the use of the concept of "sustainable diets" in different contexts worldwide, in industrialized as well as developing countries.

The Mediterranean diet was proven as good for health; it has nutritional virtues, diversity, seasonality, freshness, culture, skills. The south Mediterranean countries should avoid reproducing a Western pattern of which we perceive the limits today and should incorporate sustainable development goals into their policies Our objective is not to cultivate the past, but to become aware of abuses of food systems in the Mediterranean. Traditional knowledge and experience are wiped out in the name of modernity. Don't we have to learn from our past to ensure a sustainable modernity? It is still possible to build our future on the triad of traditional food, food industry and sustainable development including nutrition, environment and biodiversity.

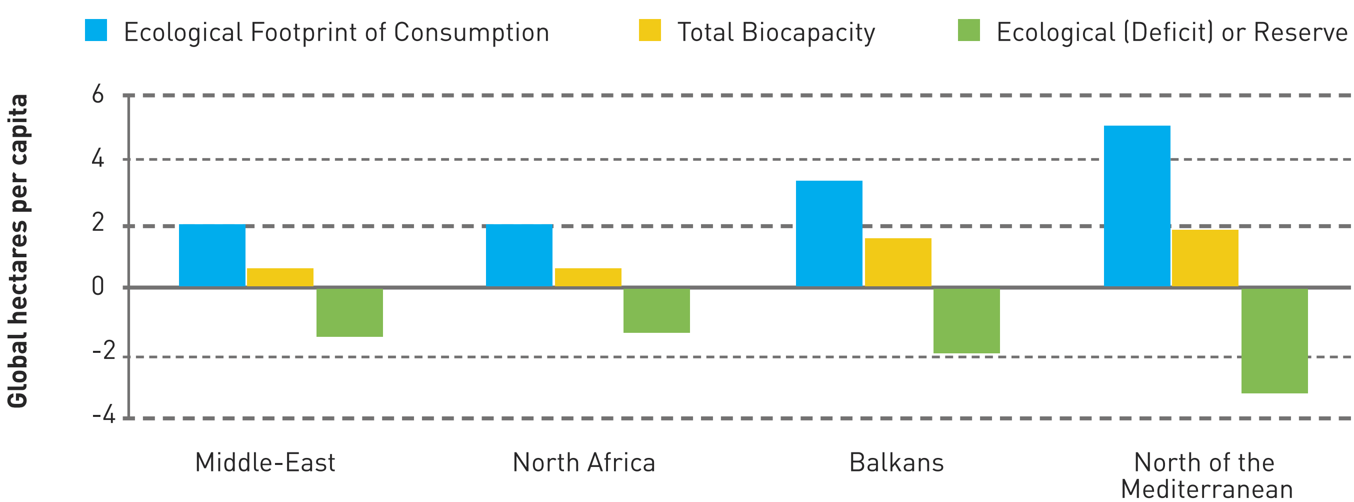

Figure 4. Balance of the total ecological footprint in the Mediterranean region.
Source: Global footprint network, 2007.

References

Aboussaleh, Y. and Ahami, A. 2009. Dietary determinants of stunting and anaemia among preadolescents in Morocco. African Journal of Food Agriculture and Development, 9: 2.

Anzid, K., Elhamdani, F.Z., Baali, A., Boëtsch, G., Levy-Desroches, S., Lôpez, P.M. Cherkaoui, M. 2009. The effect of socio-economic status and area of residence on household food variety in Morocco. Annals of Human Biology, 36: 6.

Barilla Center (2010). Double pyramid: healthy food for people sustainable food the planet. Barilla Center for Food & Nutrition, Parma, Italy.
http://www.barillacfn.com/uploads/file/72/1277731651_PositionPaper-BarillaCFN_Doppia-Piramide.pdf .

CEPF (2010). Ecosystem Profile - Mediterranean Basin Biodiversity Hotspot. For submission to the CEPF (Critical Ecosystem Partnership Fund) donor council.

Duchin F. Sustainable consumption of food: a framework for analysing scenarios about changes in diets. J Ind Ecol 2005;9:99–114.

Elloumi M. & Jouve A.-M. (2010). Extraordinary farm diversity. In: International Centre for advanced Mediterranean Agronomic Studies (CIHEAM); Mediterra Atlas: Mediterranean agriculture, food, fisheries and the rural world. Presses de Sciences Po, Paris; 132 p

Harlan, J.R. (1995). Agricultural Origins and Crop Domestication in the Mediterranean Region. Diversity, 11: 14-16.

Hawkesworth S., Dangour A.D., Johnston D., Lock K., Poole N., Rushton J., Uauy R. & Waage J. (2010). Feeding the world healthily: the challenge of measuring the effects of agriculture on health. Philosophical Transactions of the Royal Sociely, B-Biological sciences, 365, 3083-3097.

Heywood V.H. (1998). The Mediterranean region. A major centre of plant diversity. In: (Heywood VH, Skoula M eds) "Wild food and non-food plants: information networking". Proceedings of the II MEDUSA Regional Workshop (1-3 may 1997, Port El-Kantaoui, Tunisia). Cahiers CIHEAM, Options Méditerranéennes 38: 5-15.

Jana S. (1995). Factors Contribution to Crop Diversity in the Mediterranean. Diversity, 11:15.

Jouve AM, Padilla M (2007). Les agricultures périurbaines méditerranéennes à l'épreuve de la multifonctionnalité: comment fournir aux villes une nourriture et des paysages de qualité, Cahiers de l'Agriculture, Vol 16, 4, juillet-août 2007 pp 311-318.

MFAF-DK (2010). Food ▪ s carbon footprint. Ministry of Food, Agriculture and Fisheries, Danemark DK
http://www.fvm.dk/Foods_Carbon_Footprint.aspx?ID=42268

Mariotti A., Zeng N., Yoon J., Artale V., Navarra A., Alpert P. and Millstone E. & Lang T. (2008). The Atlas of Food. Earthscan, second edition, London.

Padilla M. (2008). Dietary patterns and trends in consumption. In Mediterra 2008 - The future of agriculture and food in Mediterranean countries. International centre for advanced Mediterranean studies – Paris; Presses de Sciences Po. Pp: 149- 170.

Plan Bleu (2006). Executive summary on "A Sustainable Future for the Mediterranean: The Plan Blueì ▪ s Environment and Development Outlook", edited by Guillaume Benoit and Aline Comeau 2005. 464 p. Earthscan.

Plantlife International (2010).

Reddy Sh., Lang T., Dibb S. (2009). Setting the table - Advice to Government on priority elements of sustainable diets. Sustainable Development Commission, UK.

Steinfeld H., Gerber, P., Wassenaar T., Castel V., Rosales M. & de Haan C. (2006). Livestock ▪ s long shadow: Environmental issues and options-FAO Food and Agriculture Organization of the United Nations (FAO), Rome.

Sundseth, K. (2009). Natura 2000 in the Mediterranean Region. European Commission; Environment Directorate General, Luxemburg.

Trichopoulou A. & Lagiou P. (1997). Healthy traditional Mediterranean diet: an expression of culture, history, and lifestyle. Nutr. Rev.; 55: 383–389.

Tucker G.M. & Evans M. (1997). A Conservation Strategy for the Wider Environment. BirdLife Conservation Series 6, 464 pp.

Vavilov N.J. (1951). Phytogeographic basis of plant breeding - The origin, variation, immunity and breeding of cultivated plants. Chronica Bot., 13: 1-366.

Williams J.T. & Haq N. (2002). Global research on underutilised crops – An assessment of current activities and proposals for enhanced cooperation. International Centre for Underutilised crops, Southampton, UK.

BIODIVERSITY AND LOCAL FOOD PRODUCTS IN ITALY

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Abstract
The role of biodiversity for food quality and healthy status is well recognized. The question is whether environmental changes could affect the composition and bioavailability of bioactive and other food components and in what way the production of local and traditional foods in the various Italian countries can be improved by applying advanced technologies. The great progress in technological processes (advanced technologies, innovative food equipment manufacturers), agricultural practices (food production, transport and processing) and so the changes in lifestyle led to take attention towards both local foods and functional foods as principal elements for improving food product quality and in the meantime supporting local agrobiodiversity. The main aim of this research is to identify the many different local and traditional foods in Italy, their production methods, domestic cooking and the environmental factors that may affect food quality addressing towards a healthy status. Our study has been focused on quantification of bioactive molecules (vitamins, polyphenols, carotenoids) and evaluation of ferric-reducing antioxidant power (FRAP) of selected foodstuffs, representing Italian agricultural ecotypes. FRAP value, measured on Aprica's cherries, was 18.55 mmolkg-1 (SD 1.91) and vitamin C concentration was 0.22 gkg-1 (SD 0.76). Wild strawberries presented more efficiency in the total value then literature data 62.85 mmolkg-1 (SD 3.32). In the selected agricultural ecotypes of carrots, α-carotene and β-carotene reached highest values. The antioxidant levels and their bioactivity could indicate a better potential for health for the artisan niches improving their quality and biodiversity.
The conservation and valorization of local/traditional products could increase the adoption of more sustainable agricultural systems together with the adoption of practices more respective of the environments and the natural habitats.

Introduction
The great progress in technological processes (advanced technologies, innovative food equipment manufacturers), agricultural practices (food production, transport and processing) and so the changes in lifestyle led to take attention towards both local foods and functional foods as principal elements for improving food product quality and in the meantime supporting local agrobiodiversity. Quality should be identified as valorization of traditional agricultural patrimony, peculiarity of cultivation and uniqueness of typical products. The high quality food products have significant nutritive and excellent biological properties and so they have a crucial role in the productive process and the manufacturing system in the agro-alimentary industry. Nowadays, several researches emphasize benefits that accrue to the small-scale producer and to the consumer, due to the linkage between food quality and agricultural biodiversity.

The artisan niches production, founded on quality and agricultural biodiversity and intended for local and regional use, seems to meet requirements of consumers about safety and genuineness. The local small production (niche) represents a system based on support of agricultural ecotypes cultivated by techniques based on the historical and cultural tradition of a specific territory and occurring only in their native place. Through buying locally grown produce, consumers could give their support to local producers as well as helping to revitalize rural economies. Our study represents a step within a research programme aiming to improve the valorization of different agricultural ecotypes as artisan niches, in particular their nutritional and health value. The geography influences the variation in crop growth and so the nutrient/micronutrient content varies considerably by species, genotype and ecotype and by the range of crop management practices employed. The environmental and agricultural specification could contribute to further valorization of local agricultural products by adding market value to a specific basket of products, and then can be a tool for the promotion of local products and varieties in the frame of sustainable rural development, with the adoption of practices more respective of the environments and the natural habitats. It will be clear that local and traditional foods play an important role in the food pattern of many population groups in several countries. Their nutritional quality and safety are essential elements in dealing with those foods. Over the last 15 years, several researchers have shifted towards quality that is related to antioxidants that are active in preventing widespread human diseases. Much epidemiological and experimental evidence has shown the correlation between diet and degenerative diseases in humans such as cancer and cardiovascular disease (1,2,3,4). The contents of antioxidant substances, mainly phenolic compounds, carotenoids, tocopherol and ascorbic acid have been determined in many species of fruits, vegetables, herbs, cereals, sprouts and seeds (5,6). Particular attention is given to fruits, as rich sources of phenolic compounds. Changes in antioxidant composition of the selected vegetables were linked to agricultural practices and environmental factors. The potential antioxidant effects and the high phytochemical content represent an essential tool for obtaining high quality and healthy products.

The main aim of this research was to investigate the antioxidant properties and bioactive molecules contents of selected local and traditional foods in Italy, their production methods, domestic cooking and the environmental factors that may affect food quality addressing towards a healthy status. In addition the bioactivity of polyphenolic extracts obtained from cultivated and wild chicory in human epithelial colorectal adenocarcinoma cell (caco-2) models were studied.

Material and methods

Selected foodstuffs. The foods, selected to represent Italian agricultural ecotypes, were taken from different regions of Italy: strawberry, cherry "Aprìca" from Lombardia; potato "Rotzo", raspberry "Cansiglio" from Veneto; potato "Val Belbo", pear "Madernassa" from Piemonte; apple "Limoncelle", purple carrots "Fucino" from Abruzzo; chicory, strawberry "Mara des Bois" from Calabria; chicory and plums from Lazio (Table 1).

Table 1. Selected local Italian agricultural ecotypes.

Species	Ecotypes	Origin
Fragaria vesca	strawberry	Lombardia
Prunus padus	cherry	Lombardia
Solanum tuberosum	potato	Veneto
Rubus idaeus	raspberry	Veneto
Solanum tuberosum	potato Val Belbo	Piemonte
Pyrus communis	pear Madernassa	Piemonte
Malus domestica	apple Limoncella	Abruzzo
Daucus carota	purple carrot	Abruzzo
Chicorium intybus	chicory	Calabria, Lazio
Fragaria ananassa	strawberry " Mara des Bois"	Calabria
Prunus domestica	plum	Lazio

We have analysed some of these products cooked because our aim was to study the food as it used to be consumed. Chicory, potatoes and carrots are used also as cooked vegetables. In addition, for potatoes, we analysed potatoes cultivated following two types of cultural practices, organic and integrated, in the same region.

Chemicals and standards. The organic solvents used for the separation of carotenoids, ascorbic acid and polyphenols were of HPLC grade and purchased from Carlo Erba, Milan, Italy. Other organic solvents and chemicals used in the extraction procedures were of analytical grade (Sigma). Standard regression lines pure were purchased from Sigma.

Sample preparation. A representative sample from each treatment was homogenized in a Waring blender for 1 minute. Two replicates were prepared from each sample. Aliquots of the samples were stored at -80°C until the polyphenols, carotenoids, vitamin C analysis were conducted.

Methodologies. The total antioxidant activity was measured by ferric-reducing antioxidant power as proposed by Benzie and Strain (8). The obtained supernatants were combined and used directly for assay (9). The absorbance was recorded through the use a Tecan Sunrise® plate reader spectrophotometer. Total ascorbic acid (AA+DHAA) was extracted and quantified by HPLC system according to the method of Margolis *et al.* (10), with some modifications (11). Chromatographic separation was carried on a 250 x 4.6 mm Capcell Pak NH2 column (Shiseido, Tokyo, Japan), using ESA series HPLC, equipped an eight-channel coulometric electrode array detector and an ESA coularray operating software that control the equipment and perform data processing (ESA, Chemsford, MA, USA). Phenolics were hydrolyzed to obtain total free forms, and extracted as described by Hertog *et al.* (12). Quantitative analysis was performed using an ESA series (MODEL 580) of HPLC solvent delivery module, an ESA 5600 eight-channel coulometric electrode array detector and an ESA coularray operating software that control the equipment and perform data processing (ESA, Chemsford, MA, USA).

Carotenoids were determined as described by Sharpless *et al.* (13). The extracts were analysed by a Perkin-Elmer ISS 200 series HPLC system. The eluents were methanol/acetonitrile/tetrahydrofuran (50:45:5). The peaks were detected with a variable spectrophotometric detector (Perkin-Elmer LC-95, Norwalk, CO, USA) connected to a personal computer Pe Nelson mod 1020 (Perkin-Elmer). The detection wavelengths was 450 nm for carotenoids (14).

MTT test to evaluate cytotoxicity of phenolic chicory extracts on Caco-2 cells was used. The MTT colorimetric assay determines the ability of viable cells to convert a soluble tetrazolium salt (MTT) into an insoluble formazan precipitate. The ability of cells to reduce MTT provides an indication of mitochondrial integrity and activity which, in turn, may be interpreted as a measure of viability and/or cell number. The assay has therefore been adapted for use with cultures of exponentially growing cells such as the human epithelial colorectal adenocarcinoma cells. Determination of their ability to reduce MTT to the formazan product after exposure to test compounds, enables the relative toxicity of test chemicals to be assessed.

Statistics

Data are given as the mean and standard deviation (SD). Statistical analysis was performed using student's t-test.

Results and discussion

Our study has been focused on quantification of bioactive molecules (vitamins, polyphenols, carotenoids) and on evaluation of antioxidant power of local selected foodstuffs (Table 1). It is important not only levels of phytochemicals in foodstuffs, but the contribution of foodstuffs to dietary intake (7). Detailed consumption data for fruit and vegetables in Italy are in Table 2.

Table 2. The contribution of selected foodstuffs to dietary intake.

	Total			Northwest			Northeast			Centre			South and islands		
Food	Average	SD	% cons.[a]	Average	SD	% cons.[a]	Average	SD	% cons.	Average	SD	% cons.[a]	Average	SD	% cons.[a]
Raw carrots	9.24	16.45	53.08	12.36	19.17	50.09	12.50	18.64	66.11	6.62	14.72	49.37	6.26	12.12	50.85
Potatoes	38.59	38.58	78.01	34.51	35.74	73.48	35.21	35.67	75.63	41.18	41.42	78.84	42.51	40.21	82.84
Vegetables	19.91	32.63	47.62	19.05	30.80	46.10	15.69	29.84	45.38	24.05	34.52	54.91	20.47	34.14	45.75
Apples	52.88	73.82	60.67	62.59	82.33	62.74	58.04	82.82	66.39	45.27	59.47	60.71	46.05	66.95	55.64
Pears	16.87	34.13	30.69	18.09	35.86	29.81	12.28	29.46	25.77	16.19	31.94	30.73	18.75	35.96	34.16
Cherries	3.88	16.08	8.95	1.71	10.40	5.37	1.73	9.91	4.20	5.12	19.03	11.08	6.25	20.11	13.45
Strawberries	3.51	14.00	10.72	3.93	16.55	10.92	3.71	16.28	8.96	3.66	11.84	12.59	2.94	11.05	10.36
Berries	0.61	6.28	1.77	0.26	2.28	1.91	0.31	3.16	1.12	0.14	1.79	0.76	1.39	10.37	2.63

[a] % of people who consumed food in study week.
Data from A. Turrini, A. Saba, D. Perrone, E. Cialfa and A. D'Amicis, Food consumption patterns in Italy: the INN-CA Study 1994-1996. European Journal of Clinical Nutrition 55:571-588 (2001), adapted by Aida Turrini.

In an accurate evaluation of the total antioxidant capacity, the antioxidant properties of single molecules present in a single product, but also the synergic effects of interactions between the different bioactive compounds may be considered. In addition, we have studied the relative contributions of vitamin C and phenolic compounds to the antioxidant potential of fruits and vegetables. In Table 3, the FRAP values have been shown and have been compared to values derived from literature data (9, 15).
The antioxidant capacity often could be linearly correlated with the phenolic content. So we have evaluated the content of most representative molecules in every selected product (Table 4) and we have related it to literature data (16,17, 18, 19, 20).

Fruits
Apple polyphenols have been widely observed; cinnamic acid derivatives, flavonols and anthocyanins, compounds with strong antioxidant activity, have been found mainly in cortex and in skin (21). The FRAP values for apple with peel was 7.65 mmolkg-1 (SD 0.49) and for apple without peel was 4.15 mmolkg-1 (SD 0.07). In particular, the contribution of lipophilic fraction was more than hydrophilic fraction for both apple with peel and apple without peel. According to our results, the value of the total antioxidant power, obtained for apples, should be due to contribution of flavonoids such as quercetin, epicatechin and procyanidin B(2) rather than vitamin C. In addition we have calculated that the percentage

Table 3. Ferric-reducing antioxidant power (FRAP) of selected food extracts.

Region	Food	Mean total (mmol kg^{-1})	SD	Literature data
Abruzzo	Raw carrot	0.93	0.12	1.06[c]
	Cooked carrot	0.8	0.02	
	Apple with peel	7.65	0.49	7.4[c]
	Apple without peel	4.15	0.07	3.23[c]
Calabria	Chicory	20.36	0.08	
	Strawberry (cultivated)	17.79	0.43	22.74[c]
Lazio	Chicory (cultivated)	4.61	0.38	
	Chicory (wild)	7.33	0.36	
	Plums (cultivated)	9.80	0.89	
	Plums (wild)	83.86	14.73	
Lombardia	Strawberry (wild)	62.85	3.23	28.00[c]
	Cherry	18.55	1.91	8.10[c]
Piemonte	Pear with peel	2.9	0.28	5.00[c]
	Pear without peel	1.35	0.07	
	Raw potato[a]	2.6	0	3.67[c]
	Cooked potato[a]	3.95	0.21	
	Raw potato[b]	2.6	0.14	3.67[c]
	Cooked potato[b]	4.4	0.71	
Veneto	Raw potato Rotzo	3.05	0.64	3.67[c]
	Cooked potato Rotzo	4.3	0.14	
	Raspberry	57.7	6.2	43.03[c]

[a] Organic cultivation.
[b] Integrated cultivation.
[c] Data from Pellegrini *et al.* Mol Nutr Food Res 50:1030 – 1038 (2006).
[d] Data from Khanizadeh *et al.* JFAE 5: 61-66 (2007).

Table 4. More representative bioactive molecules of selected local food extract.

Region	Food	Target molecule	Mean (mg kg-1)	SD	Literature data mean (mg kg-1)
Abruzzo	Raw carrot	α-carotene	47.88	9.28	26.60[a]
		β-carotene	116.83	3.97	85.21[a]
	Cooked carrot	α-carotene	30.63	3.56	28.38[a]
		β-carotene	81.09	7.50	88.31[a]
Calabria	Chicory	chlorogenic acid	24.1	2.31	
	Strawberry (cultivated)	coumaric acid	12.4	0.2	7–27 [b]
		quercetin	31	0.04	22.0-57.11[c]
		kaempferol	15.6	0.59	4.72-21.8[c]
Lazio	Chicory (cultivated)	vitamin C	4.43	0.69	
	Chicory (wild)	vitamin C	9.21	0.95	
Lazio	Plums (cultivated)	β-carotene	5.28	1.02	
		vitamin C	34.09	4.37	30-100[f]
	Plums (wild)	β-carotene	7.54	1.11	
		vitamin C	56.09	2.69	30-100[f]
Lombardia	Strawberry (wild)	coumaric acid	8	0.31	7–27 [b]
		quercetin	24.6	0.45	22.0-57.11[c]
		kaempferol	33.8	0.97	4.72-21.8[c]
	Cherry	vitamin C	229.2	0.76	184[d]
Veneto	Raspberry	vitamin C	222.1	1.34	152.9[e]

[a] Data from Hart and Scott, Food Chemistry 54 (1):101–111(1995).
[b] Data from Prior, *et al.* J. Agric Food Chem 46: 2686–2693 (1998).
[c] Data from Cordenunsi *et al.* J Agric Food Chem 50:2581–2586 (2002).
[d] Data from Jacob *et al.* J Nutr 133: 1826–1829 (2003).
[e] Data from Oregon Raspberry and Blackberry Commission.
[f] Data from GIL *et al.* J. Agric. Food Chem., 50: 4976–4982 (2002).

of decreasing from apple with peel to apple without peel was 46 percent. For example, in the study of Chinnici *et al.* (22), a strong divergence between the flavonol values obtained for apple peels and pulp was noticed: quercitrin (94.00 mgkg-1 (SD 36.00) of fresh wt peels to 7.76 mgkg-1 (SD 1.95) of fresh/wt pools), reynoutrin (48.9 mgkg-1 (SD 16.20) of fresh wt peels to 1.98 mgkg-1 (SD 0.50) fresh/wt pools), avicularin (110.00 mgkg-1 (SD 32.90) of fresh/wt peels to 2.27 mgkg-1 (SD 0.46 fresh/wt pools).

For Aprica's cherries, the FRAP value 18.55 mmolkg-1 (SD 1.91) was higher than the literature data (16). In addition the contribution to value of lipophilic fraction and hydrophilic fraction were respectively 8.69 mmolkg-1 (SD 1.12) and 9.87 mmolkg-1 (SD 0.81).

For Aprica's cherries vitamin C concentration reached 0.22 g kg-1 (SD 0.76). The activities of phenoloxidase and ascorbic acid oxidase enzymes during storage contributed to the total content of ascorbic acid (23). Relevant levels of anthocyanins and ascorbic acid (AA) were found in the juice produced from blackcurrants, elderberries, sour cherries (24). Therefore, it is interesting to compare the vitamin C content to the values found for total antioxidant capacity. The percentage contribution of AA to the total antioxidant capacity (FRAP value) was 14 percent. TAC of cherry should be tightly correlated to vitamin C content.

Wild strawberries presented more efficiency in the

FRAP value than literature data 62.85 mmolkg-1 (SD 3.32), while for cultivated strawberries 17.79 mmolkg-1 (SD 0.43) (Table 3), FRAP values are less than literature data (9). Recent studies have shown the correlation between the phenolic constituents and antioxidative (25) and anticarcinogenic (26) properties of berries, as strawberries and berries of the genus Vaccinium. p-Coumaric acid derivatives, ellagic acid, quercetin 3-O-glycoside, and kaempferol 3-O-glycoside were detected (27,28,29). The occurrence of p-coumaroylglucose, quercetin 3-glucoside, quercetin 3-glucuronide, kaempferol 3-glucoside, and kaempferol 3-glucuronide was reported in strawberries and ellagic acid was also described as an important phenolic constituent of this fruit (30). These bioactive molecules were selected for their proposed health promoting effects as antioxidants and anticarcinogens (31). Compared to literature data, wild strawberries (from Lombardia) show an antioxidant power higher and p-Coumaric, quercetin and kaempferol content, too. So, the high content of bioactive molecules and the high antioxidant power value demonstrated as strawberries of "Aprìca" should be seen as ecotype representing a quality cultivation. Moreover, in the study of Häkkinen (32), varietal differences were observed in the contents of flavonols and phenolic acids among six strawberry and four blueberry cultivars studied. Scalzo *et al.* (33), analysing both wild and cultivated strawberries, as indicated by the Trolox Equivalent Antioxidant Capacity (TEAC), found antioxidant activities of wild strawberries higher than cultivated strawberries (34). From elucidation of specific flavonol glycosides in cranberry, quercetin-3-arabinoside was found in both furanose and pyranose forms in cranberry (35). Strawberries contain high levels of antioxidants. Phenolic phytochemicals probably play a large role than previously thought in total antioxidant activity (36).

Wild plums (from Lazio) showed significantly higher FRAP value (83.36±14.73 mmol kg-1) than cultivated ones (9.08±0.89 mmol kg-1). In recent years antioxidant activity and the content of total phenolic compounds of several plum cultivars have been investigated in order to suggest plum varieties rich in antioxidants, which may possibly exert beneficial effects on human health. Gil *et al*. (2002) have found close correlations between antioxidant capacities and both the anthocyanins and total phenolics content (37).

The contributions of phenolic compounds to antioxidant activity were much higher than those of vitamin C and carotenoids. In Table 4 observed β-carotene content was 7.54 mg kg-1 (SD 1.11) and 5.2 mg kg-1 (SD 1.02) in wild and cultivated plums respectively, while ascorbic acid content was 56.96 mg kg-1 (SD 2.69) and 34.09 mg kg-1 (SD 4.37) respectively for wild and cultivated plums.

From our data reported in Table 3, FRAP value for pear with peel was 2.90 mmolkg-1 (SD 0.28) and for pear without peel was 1.35 mmolkg-1 (SD 0.07). In addition we have calculated that the percentage of decreasing from pear with peel to pear without is 53 percent. Leontowicz *et al*. observed a strong divergence between pear skin and pear pulp (38). In fact, in several studies, the antioxidant levels were found to be higher in the skin than in the pulp. Finally, the main phenolics found in pear are leucocyanidin, catechin, epicatechin, chlorogenic acid, quercitrin and quercetin (39). The total antioxidant activity expressed as FRAP value was found to be 57.70 mmol/kg (SD 6.20); in particular, the contribution to value of lipophilic fraction and hydrophilic fraction were respectively 43.00 mmol/kg (SD 7.55) and 14.64 mmol/kg (SD 1.36). The high contribution to antioxidant activity is attributed to higher content of total phenolics, flavonoids, and anthocyanins in red raspberry fruits (40). Vitamin C contributes only 4.3 percent of the total antioxidant activity (41).

Vegetables

Comparing the results obtained in this work with those found in literature, no differences for antioxidant capacity were recorded in raw and cooked carrots (8). The percentage of decreasing was found to be 14 percent. Carotenoids are the main representative antioxidant molecules of this vegetable: β-carotene (60–80%), α-carotene (10–40%), lutein (1–5%) and the other minor carotenoids (0.1–1%)(42). α-carotene and β-carotene levels decreased after boiling: the percentages of decreasing were found to be 0.36% and 0.31% for α-carotene and for β-carotene respectively. In these agricultural ecotypes α-carotene and β-carotene values are higher than those shown in literature data (17). In addition β-carotene values were higher than α-carotene for both raw and cooked carrots (43).

Chicory represents a main source of micronutrients: in fact, it easily grows year-round, due to its ability to resist to high temperatures. It should be an interesting and cheap source of antioxidant phenolic extracts. The chicory (from Calabria) FRAP value observed was higher 20.36 mmolkg-1 (SD 0.08), than the value 6.72 mmolkg-1 reported in literature and the observed value in chicory from Lazio (4.43 and 9.21 mmolkg-1 respectively for wild and cultivated chicory): this could suggest a better benefit power for the human health. The results obtained indicate that chicory could be a remarkable source of antioxidants (44). The main representative compound of chicory was found to be the chlorogenic acid 24.1 mg kg-1 (SD 2.31). To improve the quality of chicory ecotypes, the phenolic content and composition of different chicory varieties have been previously investigated considering the influence of variety, processing and storage on this composition (45). In addition differences between the way of cooking were observed in chicory from Lazio (Figure 1):

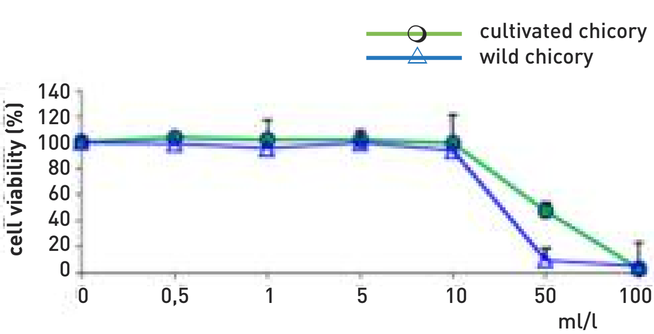

Figure 1. Effect of cultivated and wild chicory extracts on CaCo-2 viability.

lutein and β-carotene values were significant higher in pan-fried product than fresh product ($P \leftarrow 0.02$ and $P \leftarrow 0.05$ respectively) for cultivated chicory, while significantly higher values of β-carotene were observed in boiled wild chicory than wild fresh ($P \leftarrow 0.05$) and lutein was significantly higher in wild fresh than wild pan-fried chicory ($P \leftarrow 0.02$). This could be due to the greater extractability of carotenoids after cooking, while their their low contribution to total antioxidant capacity is enhanced by higher values of TAC in both wild and cultivated fresh chicory.

In potatoes, a slight increase in the FRAP values was observed after cooking. The percentage range of increasing was found to be 41–70 percent. Indeed the increase of reducing power may be correlated to release of glucosydes from food matrix after cooking (Table 3). After cooking, potato varieties differ in antioxidant values from each other, while antioxidant levels do not change in fresh potatoes. The very low values of antioxidant activity were found in watery vegetables such as potato, marrow and cucumber. In addition, the chemical components of the potato and interactions occurring during cooking, influenced the quality of potatoes and the texture of the cooked tubers (46). No remarkable differences were found in antioxidant activity between the several varieties of potatoes.

Bioactivity test

Regarding potential bioactivities, the chicory extracts seem to cause a high cytotoxicity in human epithelial colorectal adenocarcinoma cells (caco-2) by reducing cell viability to values lower than 10 percent. The results indicate that the polyphenolic extract of wild chicory possesses a marked cytotoxicity compared to cultivated chicory reducing cell viability lower than 10 percent using 50 ml/l of the extract (Figure 2).

Conclusion

Our findings show that local products have a distinctive and unique nutritional value. Their antioxidant

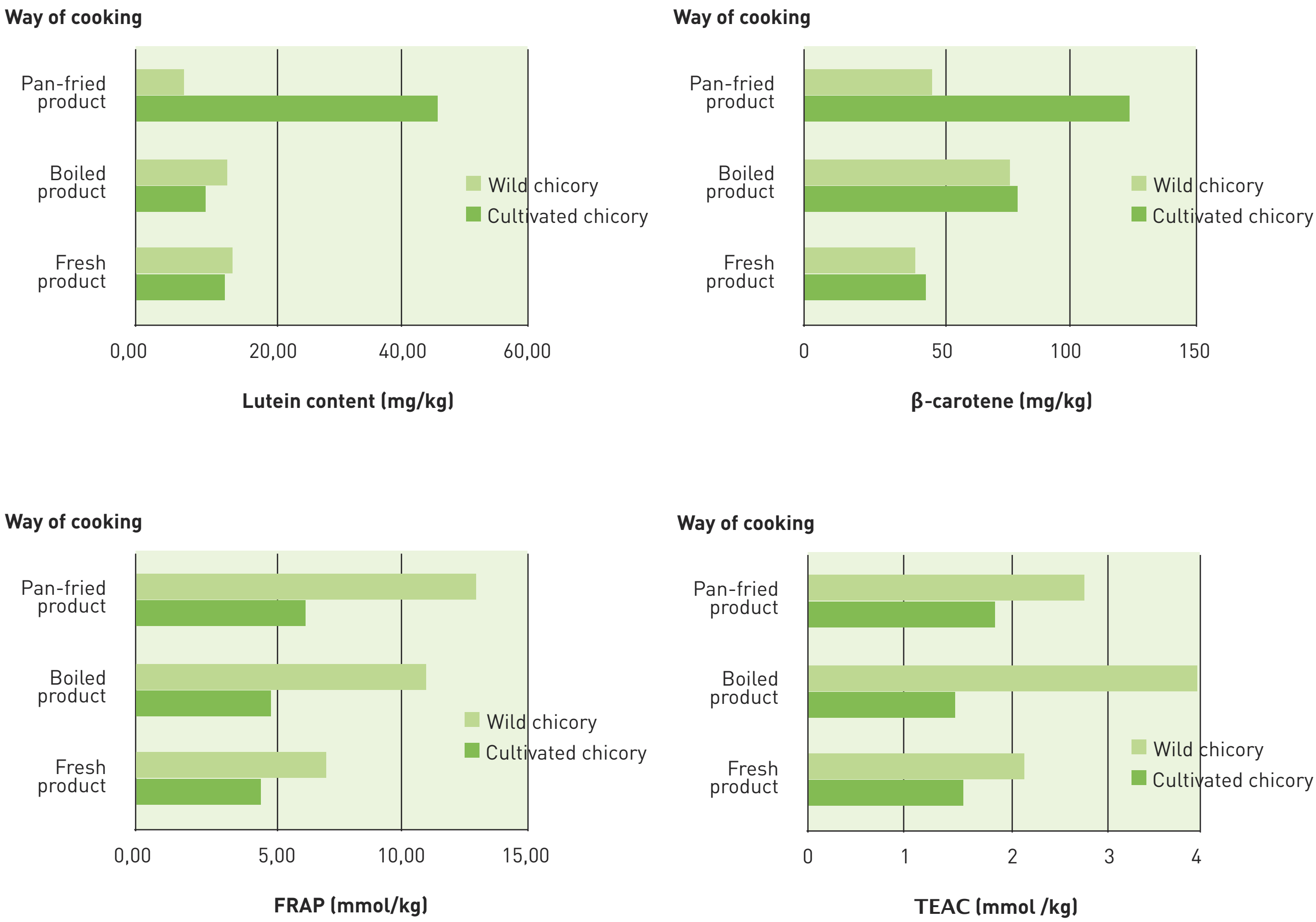

Figure 2. Effect of way of cooking on bioactive molecules and total antioxidant capacity in cultivated and wild chicory from Lazio.

levels and their bioactivity could indicate a better potential for health. Several antioxidant capacities for Valtellina typical foodstuffs appear to have higher values compared to literature data. A strong difference has been obtained for cherries of "Aprìca". Chicory (from Calabria and Lazio) represents an important source of micronutrients, that give to this vegetable a resistance to cold temperatures, consenting growth of the plant during all year. It needs to be underlined that wild chicory appears to have higher phytochemicals and its extracts seem to exert cytotoxicity in human epithelial colorectal adenocarcinoma cell (caco-2) and so promoting good health and preventing or modulating diseases.

Our data highlight the direct linkages between biophysical attributes of location and agricultural potential to improve crop growth models. On this basis the typical local production mostly in terms of quality and safety of the products should become a base for maintaining a correct nutritional plane. In addition, the conservation and valorization of local/traditional products could increase the adoption of more sustainable agricultural systems together with the adoption of practices more respective of the environments and the natural habitats.

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References

Etminan M, Takkouche B and Caamano-Isorna F, The role of tomato products and lycopene in the prevention of prostate cancer: a meta-analysis of observational studies. Cancer Epidemiol Biomark Prev 13:340-34 (2004).

Thompson LU, Antioxidants and hormone-mediated health benefits of whole grains. Crit Rev Food Sci Tech 34:473-497 (1994).

Aruoma OI, Antioxidant actions of plant foods: use of oxidative DNA damage as a tool for studying antioxidant efficacy. Free Radic Res 30:419-27 (1999).

Allen RD, Dissection of oxidative stress tolerance using transgenic plants. Plant Physiol 107: 1049-1054 (1995).

Beecher GR, Overview of dietary flavonoids: nomenclature, occurrence and intake. J Nutr 133:3248S-3254S (2003).

Kahkonen MP, Hopia AI, Vuorela HJ, Raucha JP, Pihlaja K, Kujala TS and Heinonen M, Antioxidant activity of plant extracts containing phenolic compounds. J Agric Food Chem 47: 3954–3962 (1999).

Turrini A, Saba A, Perrone D, Cialfa E, and D'Amicis A, Food consumption patterns in Italy: the INN-CA Study 1994-1996. European Journal of Clinical Nutrition 55:571-588 (2001).

Benzie IFF and Strain JJ, The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the assay. Anal Biochem 239:70-76 (1996).

Pellegrini N, Serafini M, Colombi B, Del Rio D, Salvatore S, Bianchi M and Brighenti F, Total antioxidant capacity of plant foods, beverages and oils consumed in Italy assessed by three different in vitro assays. J Nutr 133:2812-2819 (2003).

Margolis SA and Schapira R, Liquid chromatographic measurement of L-ascorbic acid e D-ascorbic acid in biological samples. J Chromatogr 690: 25-33 (1997).

Serafini M, Bugianesi R, Salucci M, Azzini E, Raguzzini A and Maiani G, Effect of acute ingestion of fresh and stored lettuce (Lactuca sativa) on plasma total antioxidant capacity and antioxidant levels in human subjects. British Journal of Nutrition 88: 615-623 (2002).

Hertog MGL, Hollman CH and Vanema DP, Optimization of a qualitative HPLC determination of a potentially anticarcenogenic flavonoids in vegetables and fruits. J Agric Food Chem 40:1591-1598 (1992).

Sharpless KA, Arce-Osuna M, Thoma JB and Gill ML, Value assignment of retinyl palmitate, tocopherol and carotenoid concentrations in standard reference material 2383 (Baby food composite). J AOAC Int 82: 288-296 (1999).

Maiani G, Pappalardo G, Ferro-Luzzi A, Raguzzini A, Azzini A, Guadalaxara A, Trifero M, Frommel T and Mobarhan S. Accumulation of beta-carotene in normal colorectal mucosa and colonic neoplastic lesions in humans. Nutr Cancer 24: 23-31, (1995).

Khanizadeh S, Tsao R, Rekika D, Yang R and DeEll J, Phenolic composition and antioxidant activity of selected apple genotypes. JFAE 5: 61-66 (2007).

Jacob RA, Spinozzi GM, Simon VA, Kelley DS, Prior RL, Hess-Pierce B and Kader AA, Consumption of cherries lowers plasma urate in healthy women. J Nutr 133:1826-1829 (2003).

Hart DJ and Scott KJ, Development and evaluation of an HPLC method for the analysis of carotenoids in foods, and the measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. Food Chemistry 54 (1):101-111(1995).

Oregon processors

Cordenunsi BR, do Nascimento JR, Genovese MI and Lajolo FI, Influence of cultivar on quality parameters and chemical composition of strawberry fruits grown in Brazil. J Agric Food Chem 50 :2581 -2586 (2002).

Prior RL, Hoang H, Gu L, Wu X, Bacchiocca M, Howard L, Hampsch-Woodill M, Huang D, Ou B and Jacob RA. Assays for hydrophilic and lipophilic antioxidant capacity (oxygen radical absorbance capacity (ORACFL) of plasma and other biological and food samples. J Agric Food Chem 51:3273–3279 (2003).

Ju Z and Bramlage WJ, Phenolics and lipid-soluble antioxidants in fruit cuticle of apples and their antioxidant acivities in model systems. Post Biol Techn 16:107–118 (1999).

Chinnici F, Bendini A, Gaiani A and Riponi C, Radical scavenging activities of peels and pulps from cv. Golden Delicious apples as related to their phenolic composition. J Agric Food Chem 52:4684-4689 (2004).

Salunkhe DK, Boun HR, Salunkhe DK, Boun HR, Reddy NR, Storage, processing and nutritional quality of fruits and vegetables: fresh fruits and vegetables. CRC Press Inc., Boston, vol. 1 (1991).

Rababah TM, Ereifej KI, Howard L, Effect of ascorbic acid and dehydration on concentrations of total phenolics, antioxidant capacity, anthocyanins, and color in fruits. J Agric Food Chem 53:4444-4447 (2005).

Netzela M, Strass G, Kau l, Bitschc I, Dietrich H and Bitsch, In vivo antioxidative capacity of a composite berry juice. Food Res int 35:213–216 (2002).

Bomser J, Madhavi DL, Singletary K, Smith MA, In vitro anticancer activity of fruit extracts from Vaccinium species. Planta Med 62:212-216 (1996).

Mosel HD and Hermann K, The phenolics of fruit. III. The contents of catechins and hydroxycinnamic acids in pome and stone fruits. Z. Lebens. Unters-Forsch 154:6-11 (1974).

Rommel A and Wrolstad RE, Ellagic acid content of red raspberry juice as influenced by cultivar, processing, and environmental factors? J Agric Food Chem 41:1951-1960 (1993)a

Mabry TJ, Markham KR and Thomas MB, The aglycone and sugar analysis of flavonoid glycosides. In the systematic identification of flavonoids. Springer-Verlag, New York (1970).

Rommel A and Wrolstad RE, Influence of acid and base hydrolysis on the phenolic composition of red raspberry juice. J Agric Food Chem 41:1237-1241 (1993).

Williamson G, Plumb GW, Uda Y, Price KR and Rhodes MJC, Dietary quercetin glycosides: antioxidant activity and induction of the anticarcinogenic phase II marker enzyme quinone reductase in Hepalclc7 cells. Carcinogenesis 17:2385-2387 (1996).

Häkkinen S, Flavonols and phenolic acids in berries and berry products. Kuopio University Publications D. Medical Sciences. (shared supervision with University of Kuopio), (2000).

Scalzo J, Politi A, Pelligrini N, Mezzetti B and Battino M, Plant genotype affects total antioxidant capacity and phenolic contents in fruit. Nutrition 21 : 207–213 (2005).

Proteggente AR, Pannala AS, Paganga G, Van Buren L, Wagner E, Wiseman S, van de Put F, Dacombe C and Rice-Evans CA, The antioxidant activity of regularly consumed fruit and vegetables reflects their phenolic and vitamin C composition. Free Radic Res 36:217-233 (2002).

Vvedenskaya IO, Rosen RT, Guido JE, Russell DJ, Mills KA and Vorsa N, Characterization of flavonols in cranberry (Vaccinium macrocarpon) powder. J Agric Food Chem 52:188-95 (2004).

Meyers KJ, Watkins CB, Pritts MP and Liu RH, Antioxidant and antiproliferative activities of strawberries. J Agric Food Chem 51: 6887-6892 (2003).

Gil M. I., Tomaa S-Barberaa N F., A Betty Hess-Pierce, and A. A. Kader Antioxidant Capacities, Phenolic Compounds, Carotenoids, and Vitamin C Contents of Nectarine, Peach, and Plum Cultivars from California J. Agric. Food Chem 50: 4976-4982 (2002).

Leontowicz M, Gorinstein S, Leontowicz H, Krzeminski R, Lojek A, Katrich E, Milan i, Martin-Belloso O, Soliva-Fortuny R, Haruenkit R and Trakhtenberg S, Apple and pear peel and pulp and their influence on plasma lipids and antioxidant potentials in rats fed cholesterol-containing diets. J Agric Food Chem 51 (19), 5780 -5785 (2003).

Schieber A, Keller P and Reinhold C, Determination of phenolic acids and flavonoids of apple and pear by high-performance liquid chromatography. J Chromatogr A 910:265–273 (2001).

Liu M, Li XQ, Weber C, Lee CY, Brown J and Liu RH, Antioxidant and antiproliferative activities of raspberries. J Agric Food Chem 50:2926-2930 (2002).

Kalt W, Forney CF, Martin A and Prior RL, Antioxidant capacity, vitamin C phenolics, and anthocyanins after fresh storage of small fruits. J Agric Food Chem 47:4638-4644 (1999).

Chen BH, Peng HY and Chen HE, Changes of carotenoids, color, and vitamin A contents during processing of carrot juice. J Agric Food Chem 43:1912–1918 (1995).
Alasalvar C, Grigor JM, Zhang D, Quantick PC and Shahidi F, Comparison of volatiles, phenolics, sugars, antioxidant vitamins, and sensory quality of different colored carrot varieties. J Agric Food Chem 49:1410–1416 (2001).

Llorach R, Tomas-Barberan FA and Ferreres F, Lettuce and chicory byproducts as a source of antioxidant phenolic extracts. J Agric Food Chem 52:5109-5116 (2004).

Stratil P, Klejdus B and Kuban V, Determination of total content of phenolic compounds and their antioxidant activity in vegetables evaluation of spectrophotometric methods. J Agric Food Chem 54:607-616 (2006).

Jarvis MC, Mackenzie E and Duncan HJ, The textural analysis of cooked potato. 2. Swelling pressure of starch during gelatinisation. Potato Research 35: 93–102 (1992).

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ORGANIC FARMING: SUSTAINABILITY, BIODIVERSITY AND DIETS

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Abstract
The current agrofood system is one of the most responsible for the ecosystem degradation, in particular, the biodiversity loss. Moreover, it has proved to be unable to addres hunger and malnutrition. Biodiversity in the food systems is absolutely crucial for both a sustainable food production and food security. Diets based on different food species promote health by addressing the problem of micronutrient and vitamin deficiencies. Therefore, it seems that the transition towards sustainable forms of agriculture cannot be deferred further.
The organic food production is seen having the potential to contribute substantially to the global food supply and reduce the environmental impact of the conventional agriculture.
This paper summarizes the evidence present in the scientific literature on these subjects and offers insights into the links between organic food production, sustainability, biodiversity and healthy diets.

Introduction

The current globalized food system is one of the most responsible for the ecosystem degradation. Agriculture alone contributes about 13 percent to the global human-induced greenhouse gas emissions, but this rate increases ranging from 17 to 32 percent if the indirect emissions (fertilizers production and distribution, farm operations, land conversion to agriculture) are included (Bellarby *et al.*, 2008). Therefore, the so-called "industrial agriculture" based on the adoption of large-scale farming systems, on the massive use of fertilizers, that needs high energy inputs to have high yields and to maintain a constant level of production, is widely considered no longer sustainable. Overall, if one takes into account that it failed to address hunger and malnutrition.
Currently, it is widely accepted that facing the dual challenge of achieving food security and reducing the environmental impact of food production, it is necessary to take steps of transition towards sustainable forms of agriculture (Hoffmann, 2011).

Organic farming and sustainability

Interest in organic production has grown appreciably over the last few decades in the world (Willer and Kilcher, 2011). According to EC Reg. No. 834/2007, organic production is defined as: "...an overall system of farm management and food production that combines the best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preferences of certain consumers for products produced using natural substances and processes".
Organic management practices exclude such conventional inputs as synthetic pesticides and fertilizers, instead putting the emphasis on building up the soil with compost additions and animal and green manures, controlling pests naturally, rotating crops and diversifying crops and livestock.
Organic agriculture is generally considered as having a lower environmental impact than conventional agriculture. According to Hoffmann (2011), a conversion to organic agriculture could significantly reduce the greenhouse gas (GHG) emissions (reduction of the use of industrial nitrogen-fertilizer and of the soil-based N2O emissions). However, an examination of the scientific literature demonstrates that the lower environmental impact of organic agriculture is true for many foods but not for all, and not for all the classes of environmental impact. (Foster *et al.*, 2006). An energy analysis carried out at the Rodale Institute showed a 33 percent reduction in fossil-fuel use for organic farming systems in comparison with the equivalent conventional ones (Pimentel, 2005). Fewer energy input requirements have been observed for the organic production of wheat, beef, sheep and pork meat, oil seed rape, milk (Foster *et al.*, 2006; Williams *et al.*, 2006); whereas the energy inputs were higher for organic poultry meat and eggs. No difference was observed, instead, between organic and conventional potato production (Foster *et al.*, 2006).
In terms of land use, organic production generally

requires substantially more farmland than the conventional one (Cederberg and Mattsson, 2000; Foster *et al.*, 2006).

On the other hand, organic agriculture has a significant ability to sequester large amounts of atmospheric carbon into the soil (Hepperly *et al.*, 2007), thus contributing to counteracting greenhouse gases. Therefore, carbon sequestration of organic farming is crucial in assessing the environmental impact (Niggli *et al.*, 2008).

Leaching of nutrients, nitrogen in particular, is responsible for much of the environmental damage caused to many ecosystems by intensive agriculture (Hansen *et al.*, 2001). In organic production only organic fertilizers can be used to supply the soil with nitrogen. From the scientific literature, the nitrogen leaching in organic farming results lower than that occurring in conventional agriculture (Knudsen *et al.*, 2006; Hansen *et al.*, 2001). However, nitrogen leaching depends not only on the type of fertilizer used, but also on the management practices (Knudsen *et al.*, 2006). In fact, the mineralization of organic fertilizers is slow and problems with the supply of nitrogen can occur, particularly when the demands of the plants are high (Kelderer *et al.*, 2008).

The lower yields generally observed in the organic crop production are ascribed to the limited availability of nitrogen in the organic systems (Doltra *et al.,* 2011). By an efficient and careful management of the nutrient supply to the plants, it is possible to counterbalance the negative effects on the yields (Doltra *et al.*, 2011; Crews and Peoples, 2004; Hansen *et al.*, 2001; Pang and Letey, 2000). Mader *et al.* (2002) reported a reduction of only 20 percent of the yield of grain crops in organic systems, although the fertilizer input was reduced by 34–53 percent. Pimentel *et al.* (2005) reported yields in organic maize and soybean comparable to those of conventional production, suggesting that organic crop production can be competitive with conventional faming.

Organic farming and biodiversity

Agricultural biodiversity (agrobiodiversity) is fundamental to agricultural production, food security and environment conservation. Agrobiodiversity, in fact, includes a wide variety of species and genetic resources and also the ways in which the farmers can exploit them to produce and manage crops, land, water, insects and biota (Thrupp, 2000). Agricultural biodiversity, moreover, provides ecosystem services on farm, such as pollination, fertility enhancement, insect and disease management. Over the last 40 years the model and patterns of industrial agriculture have caused serious degradation of natural resources and, in particular, biodiversity: loss of plant genetic resources, livestock, insect and soil organisms. The erosion of biodiversity is manifested both within farming systems and off farms, in natural habitats.

A principal objective of organic farming is to maintain, to enhance the natural fertility of the soil. Organic farming systems which involve the use of catch crops, the recycling of crop residues, the use of organic fertilizers and perennial crops, are assumed to promote higher levels of organic matter and biological activity in the soil (number and variety of soil organisms). Microorganisms, like bacteria or fungi, play a central role in maintaining the fertility of the soil through the decomposition of organic matter. Several studies have demonstrated an increase in the biodiversity, biological activity and fertility in the soil managed by organic systems (Bengtsson *et al.*, 2005; Pimentel *et al.*, 2005; Mader *et al.*, 2002). Moreover, in organic farms it has been observed a higher diversity and abundance of birds, pollinator, insect and herbaceous plants (Holzschuh *et al.*, 2008; Rundlöf *et al.*, 2008a; Rundlöf *et al.*, 2008b; Holzschuh *et al.*, 2007) than in conventional ones.

However, Gabriel *et al.* (2010) have demonstrated that within a farm biodiversity is influenced by both management within the farm and management of surrounding farms, thus highlighting the crucial role of the landscape. Belfrage *et al.* (2005) compared diversity and abundance of birds, butterflies, bumblebees and herbaceous plants between organic and conventional farms of different sizes. They found more bird species, butterflies, herbaceous plant species, and bumblebees on the small farms compared to the large farms. The largest differences were found between the small organic and large conventional farms. However, differences were also noted between small and large organic farms: This study introduces the aspect of the farm size as a co-factor contributing to the higher biodiversity in organic farms, and the small size farms seem to behave better in terms of biodiversity than the larger ones.

Clearly, the farm size per se does not affect biodiversity. However, it is possible to state that the biodiversity results are affected by the different farm regimes and management practices that different farm sizes require.

Organic farming and sustainable diets

Fruit and vegetables contain health-related compounds, such as vitamins, dietetic fibre, antioxidants (ascorbic acid, phenolic compounds, carotenoids) whose consumption can positively contribute to human health by reducing the risk of cardiovascular and degenerative diseases (Béliveau and Gingras, 2007; Bazzano *et al.*, 2002; Ness and Powles, 1997). For these reasons, the dietary patterns grounded on scientific evidence encourage the consumption of fruit and vegetables and suggest to reduce the frequency of the consumption of meat. One of the most known dietary patterns is the so-called "Mediterranean diet", that recently has been recognized by UNESCO as an intangible heritage of humanity. The Mediterranean diet promotes the consumption of plant products typical of the countries of the Mediterranean Basin such as olive oil, cereals, legumes, fruit and vegetables.

It has been demonstrated that encouraging individuals to consume less meat and more plant-based foods may be also a measure to increase the sustainability and reduce the environmental costs of food production systems. In fact, the production of animal food has a higher global warming potential (GWP) than that of plant food (Moresi and Valentini, 2010; Duchin, 2005; Carlsson-Kanyama *et al.*, 2003; Rejinders and Soret, 2003) and needs higher arable surface than plant food production (Brandão, 2008). From a comparison between different dietary patterns combined with different production systems it resulted that: i) within the same method of production, a greater consumption of animal products translates to a greater impact on the environment; ii) within the same dietary pattern, conventional production methods have a greater environmental impact than organic methods (Baroni *et al.*, 2006).

On the whole, the evidence seems to support the opportunity of educating people, mainly in western countries, to shift their eating habits towards the increase of direct consumption of plant foods to protect their own health and the environment.

Consumer awareness of the environmental impact of the food system has increased in recent decades, thus leading to an expansion of the organic food sector (Willer and Kilcher, 2011). Consumers purchasing organic food demonstrate to have an attitude towards health (Tjärnemo and Ekelund, 2004), environment quality, food safety (Loureiro *et al.*, 2001), ethical values (animal rights) (Honkanen *et al.*, 2006). It has been suggested the existence of a potential relation between organic food and vegetarianism. The ecological motivations underlying organic food choice and vegetarian diet choice are quite similar (Honkanen *et al.*, 2006).

Consumer studies have shown that among the multiple reasons for organic preference, the belief that the organic foods are healthier than the conventional ones is one of the most important (Shepherd *et al.*, 2005). A number of studies have been published during the last two decades comparing the nutritional quality of conventionally and organically produced fruit and vegetables. It is known that crop management can affect the composition of plant material (Bourn and Prescott, 2002). Different theories have been put forward to describe the mechanisms on which the organic production system could affect the nutritional value and the content of health-related compounds (Brandt and Molgaard, 2001). However, the research on this aspect is not conclusive and only some trends have been individuated: a higher content of vitamin C, dry matter, phosphorus, titratable acidity, phenols (antioxidant) and less of nitrates in organic fruit and vegetables in comparison with conventional ones (Lairon, 2009; Bourn and Prescott, 2002; Brandt and Molgaard, 2001). The interpretation of the results of the investigations published in the scientific literature is difficult, because of methodological differences related to cultivar selection, growing conditions, sampling and analytical methods.

Most of these studies fail in describing the field experiment design and represent only one seasonal harvest. In a recently published systematic review, in which the authors adopted a series of criteria to select the comparative studies conducted over the past 50 years, only a higher content of phosphorus and values of titratable acidity in the organic products were confirmed (Dangour *et al.*, 2009). This shows that further research is needed on this subject before conclusively stating if differences exist in the nutritional quality between organically and conventionally grown fruit and vegetables.

In the decade 1999–2009 the organic agricultural land has increased from 11 million to 37.2 million ha. Australia, Argentina, the United States, China and Brazil are the countries with the most organic agricultural land. However, if the share of the organic agricultural land out of the total agricultural land is considered, small countries such as Falkland, Liechtenstein, Austria, Switzerland hold the first positions in the world. The countries with the largest numbers of organic producers are India, Uganda, Mexico, Ethiopia, Tanzania. In these countries the average farm size is low, and the conversion to organic agriculture could represent a quite easy option to the small farmers, because they are used to producing more or less "organic", with little or no application of chemical inputs.

The role of small-size farms is fundamental in preserving and enhancing biodiversity. Worldwide small farmers are those who generally practise high-diversity agriculture, both in terms of cultivated crops and varieties of a single crop. This practice is necessary also to increase food security, because it provides more options to cope with pests and diseases. Generally, the small farmers cultivate local varieties of a crop, because well adapted to local conditions and able to resist or tolerate the typical diseases of the crop.

Promoting this high diversity of crops and varieties has doubtless positive effects on human health. Fruit and vegetables have a fundamental role in diet, because they are the main natural sources of micronutrients, dietary fibre, bioactive compounds. Many factors can affect the nutritional content of horticultural crops, including climate, geography, soil, fertilization, but the differences between varieties are often by far more relevant. Interestingly, the nutrient content of the less-known cultivars and wild varieties has often resulted higher than that of the widely-cultivated cultivars, thus suggesting the need of compositional researches to characterize these products and providing data useful for their protection and use (Lutaladio *et al.*, 2010). The market where small farmers can sell their products is different from that of the large-size farms.

These latter select the crop and varieties to cultivate in a way to match the standards fixed and the amount demanded by the organized distribution chains. Instead, the final destination of the products from small-size farms is mainly represented by the local markets or the so-called short food supply chain, such as farmers' markets or other forms of direct selling from the producer to the consumer. These short supply chains are gaining more and more interest among consumers in western countries, thus creating a new relationship between agricultural and urban worlds. The organic small farms often find the commercial outlet for their products in this kind of market (Böhnert and Nill, 2006).

References

Baroni, L., Cenci, L., Tettamanti, M., Berati, M. (2006). Evaluating the environmental impact of various dietary patterns combined with different food production systems. European Journal of Clinical Nutrition, 61, 279-286.

Bazzano, L. A., He, J., Ogden, L. G., Loria, C. M., Vupputuri, S., Myera, L., Whelton, P. K. (2002). Fruit and vegetable intake and risk of cardiovascular disease in U.S. adults: the first National Health and Nutrition Examination SurveyEpidemiologic Follow-up Study. American Journal of Clinical Nutrition, 76, 93-99.

Belfrage, K., Björklund, J., Salomonsson, L. (2005). The effects of farm size and organic farming on diversity of birds, pollinators, and plants in a Swedish landscape. Ambio, 34, 582-588

Béliveau, R. and Gingras, D. (2007). Role of nutrition in preventing cancer. Canadian Family Physician, 53, 1905-1911.

Bellarby, J., Foereid, B., Hastings, A., Smith, P. (2008). Cool Farming: Climate impacts of agriculture and mitigation potential. Greenpeace International from: http://www.greenpeace.org/international/en/publications/reports/cool-farming-full-report

Bengtsson, J., Ahnström, J., Weibull, A. C. (2005). The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology, 42, 261-269.

Böhnert, E. and Nill, D. (2006). Value Chains for the Conservation of Biological Diversity for Food and Agriculture. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, Germany from: www.gtz.de/de/dokumente/en-biodiv-value-chains-2006.pdf

Bourn, D. and Prescott, J. (2002). A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. Critical Reviews in Food Science and Nutrition, 42, 1-34

Brandão, M. (2008). Food systems revisited: their evolution and sustainability implications from an interdisciplinary perspective. In: Proceedings of the Conference on Food Security and Environmental Change Linking Science, Development and Policy for Adaptation: University of Oxford, UK, from www:gecafs.org/documents/PP10Brandao.pdf.

Brandt, K., Molgaard, J. P. (2001). Organic agriculture: does it enhance or reduce the nutritional values of plant foods. Journal of the Science of Food and Agriculture, 81, 824-831.

Carlsson-Kanyama, A., Ekströmm, M. P., Shanahan, H. (2003). Food and life cycle energy inputs: consequences of diet and ways to increase efficiency. Ecological Economics, 44, 293-307.

Cederberg, C., Mattsson, B. (2000). Life cycle assessment of milk production – a comparison of conventional and organic farming. Journal of Cleaner Production, 8, 49-60

Crews, T. E., Peoples, M. B. (2004). Legume versus fertilizers sources of nitrogen: ecological tradeoffs and human needs. Agriculture, Ecosystems and Environment, 102, 279-297.

Dangour, A. D., Dodhia, S. K., Hayter, A., Lock, K., Uaury, R. (2009). Nutritional quality of organic foods: a systematic review. American Journal of Clinical Nutrition, 90, 680-685.

Doltra, J., Laegdsmand, M., Olesen, J. E. (2011). Cereal yield and quality as affected by nitrogen availability in organic and conventional arable crop rotations: A combined modelling and experimental approach. European Journal of Agronomy, 34, 83-95.

Duchin, F. (2005). Sustainable consumption of food: a framework for analyzing scenarios about changes in diets. Journal of Industrial Ecology, 9, 99-114

Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A., Mylan, J. (2006). Environmental Impacts of Food Production and Consumption: A report of the Department for Environment, Food and Rural Affairs. Manchester Business School. Defra, London.

Gabriel, D., Sait, S. M., Hodgson, J. A., Schmutz, U., Kunin, W. E., Benton, T. G. (2010). Scale matters: the impact of organic farming on biodiversity at different spatial scales. Ecology Letters, 13, 858-869.

Hansen, B., Alroe, H. F., Kristensen, E. S. (2001). Approaches to assess the environmental impact of organic farming with particular regard to Denmark. Agriculture, Ecosystems and Environment, 83, 11-26.

Hepperly, P. R., Seidel, R., Pimentel, D., Hanson, J., Douds, D. (2007). Organic farming enhances soil carbon and its benefits. In J. Kimble, C. Rice, D. Reed, S. Mooney, R. Follet, R. Lal (Eds.), Soil Carbon Management Economic, Environmental, and Societal Benefits (pp. 129-153). Boca Raton, CRC Press

Hoffmann, U. (2011). Assuring food security in developing countries under the challenges of climate change: key trade and development issues of a fundamental transformation. United Nations Conference on Trade and Development (UCTAD), Discussion Papers No. 201, February 2011.

Holzschuh, A., Steffan-Dewenter, I., Tscharntke, T. (2008). Agricultural landscapes with organic crops support higher pollinator diversity. Oikos, 117, 354-361.

Holzschuh, A., Steffan-Dewenter, I., Klejin, D., Tscharntke, T. (2007). Diversity of flower visiting bees in cereal fields: effects of farming system, landscape composition and regional context. Journal Applied Ecology, 44, 41-49.

Honkanen, P., Verplanken, B., Olsen, S. O. (2006). Ethical values and motives driving organic food choice. Journal of Consumer Behaviour, 5, 420-430.

Kelderer, M., Thalheimer, M., Andreaus, O., Topp, A., Burger, R., Schiatti, P. (2008). The mineralization of commercial organic fertilizers at 8°C temperature. In Proceedings of the 13th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing (pp. 160-166). Weinsberg, Germany.

Knudsen, M. T., Kristensen, I. S., Berntsen, J., Petersen, B. M., Kristensen, E. S. (2006). Estimated N leaching losses for organic and conventional farming in Denmark. Journal of Agricultural Science, 144, 135-149.

Lairon, D. (2009). Nutritional quality and safety of organic food. A review. Agronomy for Sustainable Development, 1, 1-9.

Loureiro, M. L., McCluskey, J. J., Mittelhammer R. C. (2001). Assessing consumer preferences for organic, eco-labelled, and regular apples. Journal of Agricultural and Resource Economics, 26, 404-416.

Lutaladio, N., Burlingame, B., Crews, J. (2010). Horticulture, biodiversity and nutrition. Journal of Food Composition and Analysis, 23, 481-485.

Mader, P., Fliessbach, A., Dubois, D., Gnst, L., Fried, P., Niggli, U. (2002). Soil fertility and biodiversity in organic farming. Science, 296, 1694-1697.

Moresi, M., Valentini, R. (2010). Dieta Mediterranea e impatto globale. Industrie Alimentari, 49, 9-20.

Ness, A. R. and Powles, J. W. (1997). Fruit and vegetables, and cardiovascular disease: A review. International Journal of Epidemiology, 26, 1-13.

Niggli, U., Fliessbach, A., Hepperly, P., Scialabba, N. (2008). Low greenhouse gas agriculture: Mitigation and adaptation potential of sustainable farming systems. Rome, FAO.

Pang, X. P., Letey, J. (2000). Organic farming: Challenge of timing nitrogen availability to crop nitrogen requirements. Soil Scientific Society American Journal, 64, 247-253.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Seidel, R. (2005). Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience, 55, 573-582;

Rejinders, L., Soret, S. (2003). Quantification of the environmental impact of different dietary protein choices. American Journal of Clinical Nutrition, 78 (Suppl.), 664S-668S.

Rundlöf, M., Nilsson, H., Smith, H. J.(2008a). Interacting effects of farming practice and landscape context on bumble bees. Biological Conservation, 141, 417-426.

Rundlöf, M., Bengtsson, J., Smith, H. G. (2008b). Local and landscape effects of organic farming on butterfly species richness and abundance. Journal Applied Ecology, 45, 813-820.

Shepherd, R., Magnusson, M., Sioden, P. O. (2005). Determinants of consumer behaviour related to organic foods. Ambio, 34, 352-359.

Thrupp, L. A. (2000). Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture. International Affairs, 76, 265-281.

Tjärnemo, H., Ekelund L. (2004). Consumers choice of organic versus conventional fruit and vegetables – The role of the grocery store. W. Bokelmann (Ed.) ISHS Acta Horticulturae 655: Proceedings of the XV International Symposium on Horticultural Economics and Management. Germany, Berlin (pp. 115-120)

Willer, H., Kilcher, L. (2011). The World of Organic Agriculture – Statistics and Emerging Trends 2011. IFOAM, Bonn, and FiBL, Frick.

Williams, A.G., Audsley, E. and Sandars, D.L. (2006). Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra. From: www.silsoe.cranfield.ac.uk, and www.defra.gov.uk

MEDITERRANEAN DIET: AN INTEGRATED VIEW

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Abstract
Malnutrition, in its two contradictory aspects concerning undernutrition and unbalanced overnutrition, is becoming one of the main threats to the worldwide population. This calls for a radical change on how food is daily produced, thought and managed. New food behaviours are to be developed, proposed and disseminated in order to actively combat both hunger and the growing phenomenon of obesity in the framework of sustainable food systems. In this context, the Mediterranean diet represents a very effective model of sustainable diet. Characterized by a healthy nutritional model, rich in olive oil, whole grains, fish, fruits and vegetables and (a little) wine, the Mediterranean diets are based on respect for the territory and on activities performed by local communities including crop harvesting, fishing, conservation, processing, preparation and consumption of food. One of the main peculiarities of the Mediterranean diets is the relevance of biodiversity. The Mediterranean Basin has a high heterogeneity of cultures and a high biodiversity. Epidemiological studies have drawn attention to certain traditional Mediterranean diets which present a high variety of plant- and animal-derived foods that favour better nutritional conditions. Scientific investigation on this kind of diet and more generally on sustainable food systems and diet requires a new holistic vision of research and innovation, based on a pro-active and very participative approach involving stakeholders. This also requires to strongly support independent and transparent research and innovation, open to the public and not subject to economic speculation in order to appropriately respond to the big worldwide questions about the food.

1. Introduction

Food security represents a multifaceted issue gripping the world, intimately linked to the big challenges humanity faces in the coming years. Proper food production and supply as well as correct and balanced diets for all are crucial and closely associated to a new ecological vision of development based on sustainability principles. Malnutrition, in its two contradictory aspects concerning undernutrition and unbalanced overnutrition, is dramatically rising, becoming one of the main threats to the worldwide population. Often coexisting in the same geographical area, it is the result of different food habits, among different social status and between old and new generations. The World Health Organization refers that 35 million of the 43 million overweight children live in developing countries, mainly in Asia but the fastest growth rates are registering in Africa (De Onis *et al.*, 2010). The contradiction more shocking is that, at the same time, hungry and undernourished are rising worldwide. According to the recent estimate of the UN Food and Agriculture Organization (FAO, 2009; UNEP, 2009), between 1990 and 2000, the number of people that live with insufficient food has increased by 34 million only in sub-Saharan Africa. In this way, food insecurity and undernourishment are now present in different countries in the world as well as conditions of overweight and obesity and vitamin and mineral deficiencies. It should be noted that, over the past two decades, food trade liberalization policy has generated dramatic implications for health, facilitating the "nutrition transition" towards unsustainable models (Kearney, 2010). Going back in the time, it should also highlight that the so-called "green revolution", while helping to reduce world hunger, has also produced significant negative impacts on the environment. The productivity of the main agriculture crops increased up to 4–5 times (Conway, 1997; Tilman *et al.*, 2002; Pimentel and Pimentel, 2008), but the consequences were very high on soil (Shiva, 2002), biodiversity, energy input use (Pimentel and Pimentel, 2008), water use (Molden, 2007), negatively impacting, among others, traditional rural livelihoods, indigenous and local cultures, accelerating indebtedness among millions of farmers and separating them from lands that have historically fed communities and families. In more recent years, the fluctuations and increases in oil and commodities prices have increased food insecurity and inequalities, with a progressive lack of access to land or to agricultural resources. Meanwhile, the actual intensive production system is also increasing alienation of peoples from nature and the historical, cultural and natural connection of farmers. Finally, it is to consider that, over the next decades, the world's population is expected to grow from 6.8 billion in 2008 (medium estimates) to 8.3 billion by 2030, and to 9.2 billion by 2050 (UNEP, 2009). The question is how to feed a growing population in a world having less soil, less water and energy. The answer can only be found in a sustainable model of production and distribution and in an appropriate public policy that makes it possible. This includes prioritizing the procurement of public goods in public spending; investing in knowledge providing adequate support to research and innovation; fostering forms of social organization that encourage partnerships, including farmer field schools and farmers' movements innovation networks; sustaining empowering women and creating a macro-economic enabling to connect sustainable farms to fair markets (UN, 2010). All the above considerations call for a radical change on how food is daily produced, thought and managed (Worldwatch Institute, 2011). New dietary behaviours are to be developed, proposed and disseminated (Nestlè, 2006; Pollan, 2010) in order to actively combat both hunger and the growing phenomenon of obesity. At the same time, it is to strongly emphasize the indissoluble linkage between ecosystems protection and fairness issues in the world. Environmental justice necessarily requires social equity and respect to the human rights among all the social groups and societies, from present and future generations. The most political act we do on a daily basis is choosing what to eat.

2. Towards sustainable food systems

The whole food chain has to be considered for moving to a real sustainable food system, starting from primary producer for arriving to the final consumer, assuring any health precaution in each step. The intimate connection among food, health and sustainable development has been well formulated by the American Public Health Association in a major policy statement (American Public Health Aassociation, 2007). Similarly, the American Dietetic Association, in its position statement, encourages environmentally responsible practices for supporting ecological sustainability of the food system (American Dietetic Association, 2007). A "sustainable food system" is "one that provides healthy food to meet current food needs while maintaining healthy ecosystems that can also provide food for generations to come with minimal negative impact to the environment. A sustainable food system also encourages local production and distribution infrastructures and makes nutritious food available, accessible, and affordable to all. Further, it is humane and just, protecting farmers and other workers, consumers, and communities" (American Public Health Association, 2007).

In this regard, it has to be remarked the convergence of the "food security" concept with that of "sustainable food system", proposed by the Sustainable Development Commission (SDC) of the United Kingdom Government that suggested a new definition of food security in terms of "genuinely sustainable food systems where the core goal is to feed everyone sustainably, equitably and healthily; which addresses needs for availability, affordability and accessibility; which is diverse, ecologically-sound and resilient; which builds the capabilities and skills necessary for future generations" (Sustainable Development Commission, 2009). Within the framework of a sustainable food system, sustainable diets assume a central role. According to FAO, sustainable diets are defined as "those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations.

Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" (FAO, 2010). Closely linked to the mentioned issues, the cultural aspects of food are highly significant. Unfortunately, food systems and related diet are facing a process of cultural homogenization and standardization. For years, indeed, conservation of different traditional cultures and knowledge were not enough considered in public policies.

Mainly in urban places, people rarely know cultural and environmental meaning of what they eat and do not usually think about the food chain and how food is produced and prepared. On the contrary, it should be affirmed that eating cannot be relegated to the mere act of taking food but it also represents the way that populations spread their selves through the environment (Murrieta *et al.*, 1999). In other words, it has to be recognized the close connection of food with space and time with a proper specific identity.

Sustainable diet calls also for following healthy lifestyle and reassigning to the food its close linkage with seasonality. Local ways of livelihood have been viewed as possible solutions, like using local production, spreading regional culinary cultures and traditions, supporting traditional trades (e.g. fishermen, shepherds, butchers, sausage makers, bakers) and encouraging people in re-dignifying the act of eating. In a global perspective, this represents a valid contribution to face the challenge of food security. It is indeed not thinkable ensuring global access to food without supporting peoples in choosing their own production and farming systems.

For a world with environmental and social justice, one should foster the capacity of governance in basal communities, leading to assert the importance of "food sovereignty" defined as the right of peoples and sovereign states to democratically determine their own agricultural and food policies (International Assessment of Agricultural Knowledge, Science and Technology for Development, 2008). Another aspect to be considered is the occasion of conviviality connected with the eating act. Conviviality is described as being synonymous with empathy "which alone can establish knowledge of other minds" (Polanyi, 1958), sharing of a certain kind of food and/or drink, reinforcing the positive feeling of togetherness on which the community's awareness of its identity is based (Schechter, 2004).

The mentioned very interconnected considerations need to be assembled and recomposed in a well-ordered coherent way, for defining and implementing suitable policies addressed to support sustainable food systems. Similarly, effective sustainable food systems and diet models are useful for transposing in practice the above conceptual schemes.

3. The global value of the Mediterranean diet model

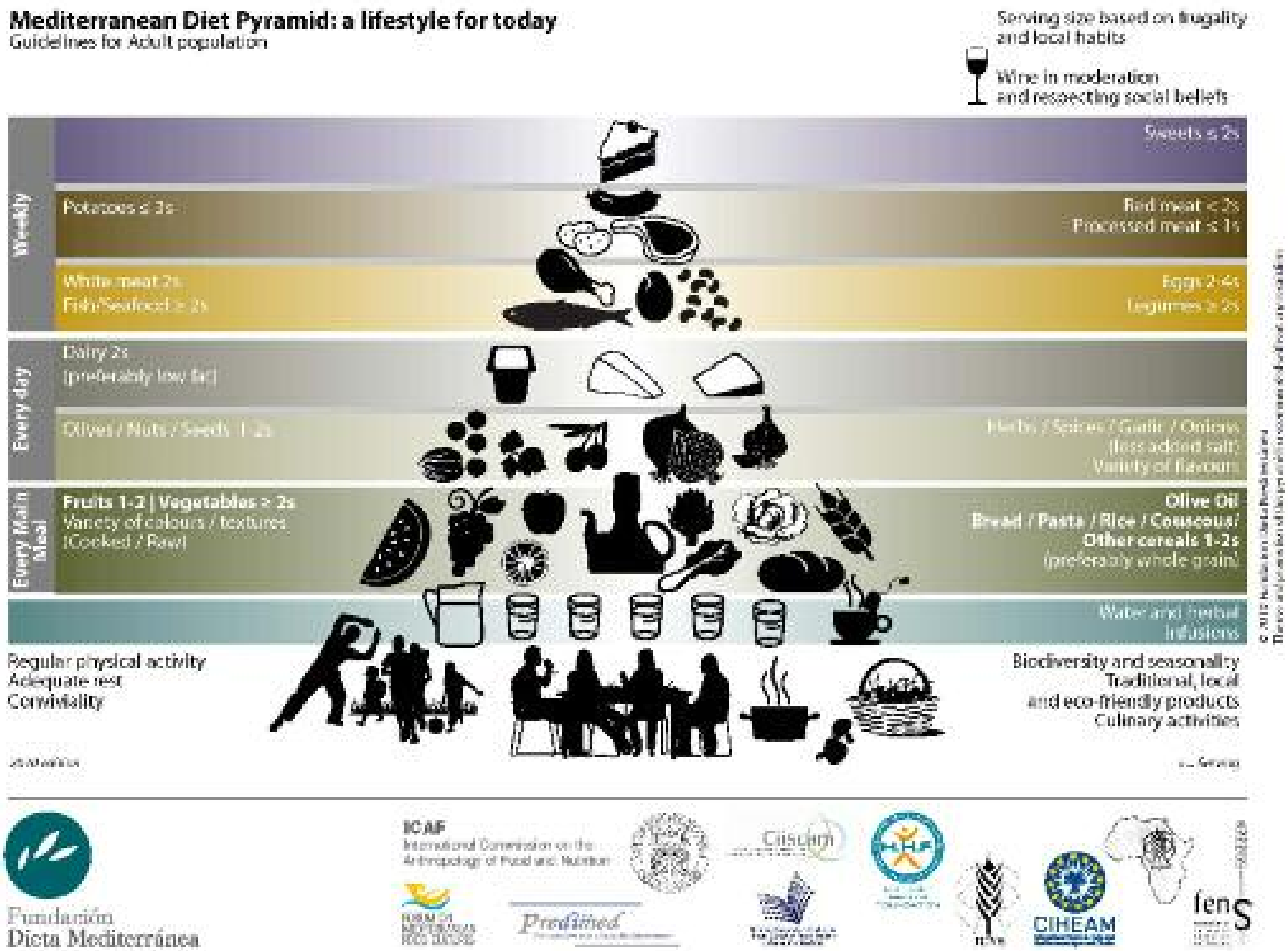
3.1 General remarks

UNESCO inscribed in 2010 the Mediterranean diet on the Representative List of the Intangible Cultural Heritage of Humanity, being recognized the importance of maintaining the healthy aspects, the good practices and traditions related to this diet as well as its peculiar cultural diversity in the face of growing globalization. This helps intercultural dialogue, and encourages mutual respect for other ways of life, taking into account that the importance of intangible cultural heritage lies in the wealth of knowledge and skills that is transmitted through it from one generation to the next.

The reason why the Mediterranean diet can be actually considered as a very effective model is that it proposes a food system scheme based on sustainability, collecting the mentioned aspects and able to contribute in pursuing real food security.

The system is characterized by a healthy nutritional model, which consists mainly of olive oil, cereals, fruit, fresh or dried, and vegetables, moderate amounts of fish, dairy products and meat, whole

Figure 1. Mediterranean Diet Pyramid



grains, many condiments and spices accompanied by wine or teas, always respecting the traditions of each community (Figure 1).

These are common characteristics, but there are many different Mediterranean diets. A famous cookbook, "Eat well and stay well" by Ancel and Margaret Keys makes it known to the United States which is exported to Europe and worldwide (Keys and Keys, 1959). Prof. Keys, after a long-term study in seven countries concluded that we should cut down drastically on saturated fat and meat and turn to vegetable oils and fresh fruit and vegetables instead in order to have lower rates of heart disease, diabetes and depression. His fortune in the second half of the twentieth century is explained by the gastronomic tourism and the development of olive cultivation and production in California and Australia. It is the effect of habits, tastes, knowledge that is confronting scramble and recompose transposed (Capatti *et al.*, 2003). The Mediterranean diets are based on the respect for the territory and biodiversity (Figures 2, 3 and 4) and on activities performed by local communities including crop harvesting, fishing, conservation, processing, preparation and consumption of food, following traditional recipes and the way and context of eating them (Serra-Majem *et al.*, 2006). They promote social interaction by communal meals and emphasize the relevant position of women that play an important role in transmitting expertise and traditional gestures as well as

Figure 2. Secular olive cultivation in Mallorca Island (Spain). Photo by Migliorini.

Figure 3. Organic cultivation of old varieties of common wheat. Photo by Migliorini.

Figure 4. *Vitis vinifera* (Zibibbo cv.) cultivated in Pantelleria Island. Photo by Carimi.

in safeguarding ancient techniques. For confirming its global value, it is also to consider that Mediterranean does not represent only a geographic dimension but a build-up of knowledge that trace historical human events. In this context at European and global level, Italy appears as an ideal reference country for the sustainable diet model because of its production of high quality and typical in all regions, its climate, the richness and diversity of its ecosystems, the type and variety of its products, its large agro-food and gastronomic traditions.

3.2 The crucial role of biodiversity conservation

During the past decade the concept of biodiversity has passed from the sphere of academic authorities to the growing attention of public opinion that considers its defence as an important issue for sustainable development. A promising approach for dealing with this theme, is to identify "biodiversity hot spots", or areas featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat. One key hot spot, the Mediterranean Basin, should be considered as a hyper-hot candidate for conservation support in light of its exceptional total (13 000) of endemic plants (Myers *et al.*, 2000). There is growing attention to the implications of cultivated biodiversity loss, affecting the livelihoods of resource-poor farmers and threatening the future prospective of agricultural developments (Tripp and van der Heide, 1996). The replacement of traditional landraces of major crops with modern cultivars had practically been completed when, in the 1970s, the green revolution in the developing world started (van de Wouw *et al.*, 2009). It is estimated that over 7 000 plant species used for food can be found across the world (Bioversity International, 2009). Harlan (1975) assesses around 360 cultivated crops and several thousand species are also collected in their wild habitats for food, fibre or medicine. However, the human diet is based on very few crops. In fact, about 20 crops play a major role in human nutrition; cereals (wheat, maize, rice, barley, sorghum and millet, Table 1), root and tuber crops (cassava, potatoes, yams and sweet potatoes) are the main starch component of the human diet (Vigouroux *et al.*, 2011).

Table 1. Land used to grow the main cereal crops in 2008. The area is based on data from FAOSTAT 2010

Crop(s)	Cultivated land in millions of hectares
Wheat	224
Maize	161
Rice, paddy	159
Barley	57
Sorghum	45
Millet	37

In addition to conventional strategies addressing the conservation and use of plant genetic resources, farmer-participatory plant breeding is flanked today (Tripp and van der Heide, 1996). Recent studies on farmer-participatory plant breeding indicate that decentralized participatory plant breeding is important to increase and stabilize productivity and maintain genetic diversity as each pocket area is occupied by the best and different genotypes. In regions characterized by high genetic diversity, landraces often evolve through crossing with wild relatives, and farmers play an important role in selecting and adapting new genotypes (Tripp and van der Heide, 1996). Farmers should be encouraged to diversify and not all select the same cultivars and species, while breeders need to guarantee that farmers can choose from a wide range of locally adapted genotypes with a different genetic base (van de Wouw *et al.*, 2009). Conservation and sustainable use of genetic resources is strategic to meet the future demand of farmers and consumers. Maintenance and survey of traditional germplasm typical of the different regions as well as its wild or semi-domesticated relatives can be of strategic impor-

Table 2. Examples of nutrient composition within varieties (per 100 g edible portion, raw).

Species	Protein (g)	Fibre (g)	Iron (mg)	Vitamin C (mg)	Beta-carotene (mcg)
Rice	5.6–14.6		0.7–6.4		
Cassava	0.7–6.4	0.9–1.5	0.9–2.5	25–34	←5–790
Potato	1.4–2.9	1–2.29	0.3–2.7	6.4–36.9	1–7.7
Sweet potato	1.3–2.1	0.7–3.9	0.6–14	2.4–35	100–23 100
Taro	1.1–3	2.1–3.8	0.6–3.6	0–15	5–2 040
Breadfruit	0.7–3.8	0.9	0.29–1.4	21–34.4	8–940
Eggplant		9–19		50–129	
Mango	0.3–1.0	1.3–3.8	0.4–2.8	22–110	20–4 320
Banana			0.1–1.6	2.5–17.5	←1–8 500
Pandanus			0.4	5–10	14–902
GAC					6 180–13 720
Apricot	0.8–1.4	1.7–2.5	0.3–0.85	3.5–16.5	200–6 939 (beta-carotene equivalent)

Source: Burlingame *et al.*, 2009.

tance to ensure a gene pool useful for future breeding programmes. Moreover, recent studies show that there is great variability in nutrient content among varieties (Table 2), demonstrating significant nutritional differences (Burlingame *et al.*, 2009). Transition from traditional to intensive farming, in addition to recent phenomena of degradation, fragmentation and loss of habitat, pollution, wildfires, non-sustainable exploitation of natural resources and climate changes, involved genetic erosion both in cultivated and wild taxa. The Council Regulation (EC) N° 870/2004 promotes *ex situ* and *in situ* conservation of genetic resources in agriculture, including forest species, as well as the use of for a long time ignored and therefore underutilized varieties. Thus, there is an urgent need to identify priority wild species and areas for conservation and to develop integrated *in situ* and *ex situ* preservation strategies, to ensure that the rich genetic diversity of crop wild relatives is protected and the biodiversity loss is halted. The Mediterranean Basin has a high heterogeneity of cultures and a high biodiversity. Epidemiological studies have drawn attention to certain traditional Mediterranean diets. However, wild gathered food species, which are an important, but fast disappearing element of these diets, so far have been largely neglected in scientific studies (Leonti *et al.*, 2006). Wild harvested plant foods include: roots and other underground parts; shoots and leafy greens; berries and other fleshy fruits; grains, nuts and seeds; and mushrooms, lichens, algae and other species (Turner *et al.*, 2011). The use of non-cultivated leaves in Mediterranean cuisine is inextricably embedded with cultural concepts describing the traditional management of natural resources and the spatial organization of the natural/cultural landscape (Pieroni *et al.*, 2005). Better conservation and use of wild food plants will be crucial to help farmers adapt to current and upcoming challenges. In the light of these considerations, the traditional use of non-cultivated food plants may represent a valuable supplementary food source for present and future generations, and thus preservation of knowledge of plant identities and uses is of major concern (Pasta *et al.*, 2011).

3.3 The importance of research and innovation

The above-cited food-related problems call for very intensive, global dimensioned and well targeted research and innovation actions. They play a fundamental role to generate new knowledge and effectively face the main obstacles in a prospect of well balanced, healthy and sustainable food systems worldwide. In this context, "social innovation" has to be recognized "as an important new field which should be nurtured" (European Commission, 2010). Results derived from research and innovation are, in a framework of sustainability, key factors for a fair growth that is, at the same time, able to combine the conservation of natural resources, public welfare and social equity. Putting more importance in dealing with social issues by research and innovation is clearly supported in the recent issued Green paper "From Challenges to Opportunities: Towards a Common Strategic Framework for EU Research and Innovation Funding" (European Commission, 2011), in which it is evidenced that the Europe 2020 strategy calls for future EU funding programmes to focus more on societal challenges. A multi- and interdisciplinary approach is also needed, involving all the actors including academic and scientific institutions, public authorities, farmers, different economic operators and citizens, focusing on the grand challenges, going beyond the current rigid thematic setting (Lund Declaration, 2009). The investigation area of sustainable food systems and diet needs to overcome disciplinary barriers and requires a new vision of research and innovation, based on a proactive stakeholders involvement. This also requires supporting independent and transparent research and innovation processes, open to the public and not subject to economic speculation. Therefore, public research in this field should assume a central role in order to appropriately respond to big worldwide questions in a very balanced manner according to the general public interest. The systemic nature of the Mediterranean diet model represents its hallmark. Consequently, research in this field cannot be limited to separate study of individual elements but calls for investigating, as well as on single "objects" (food composition, quality, safety, ...), also on the relationships between "objects" (food and environment, food and culture, food and culinary tradition, food and territorial specificities, ...). This leads to innovative research, that should devote greater emphasis to system interactions and comparisons. This is a pillar of the methodological approach that has to be pursued. Moreover, this generates a change in the way of looking at research. The researchers have to deal with multiple objectives that, in addition, are not solely traced back to traditional criteria with productivity and efficiency. Similarly, the related research results allow consumers to have the opportunity to choose food with awareness, not depending on a short-term economic assessment. They are motivated, not only by the protection of health and that of their loved ones, but also by ecological reasons as well as ethical and social solidarity considerations. The guiding principle should be the sustainability in its fullest meaning, which implies long-term research, which can combine with the immediate needs "practice" of farmers and traditional culture with those of a better understanding of natural biological processes that underlie each agro-ecosystem. Such an approach can only be founded in increasing knowledge and ability to critically analyse the world around us, which is also the foundation for scientific research. This concept is directed towards research and innovation which involves, beyond the traditional agricultural science and in a very comprehensive manner, different investigation areas, including modeling, sustainability and complexity sciences, system engineering, managing sciences, economic and social sciences. The difference – compared to conventional research – is in how to mix and combine the various skills in a holistic, interdisciplinary and very participative approach directly involving farmers that have to regain the importance that has been progressively removed from them.

4. Conclusions

One of the main global threats in the next years is the transition to unsustainable diets that are occurring in different developing countries, leading them to adopt diet habits mainly existing in the richer countries and based on energy-dense foods. This leads to the emergence, also in those countries, of an increase in diet-related diseases, that are coexistent with still present problems of undernutrition that urgently call for being faced effectively within the framework of food security (Alexandratos, 2006). At the same time, climate changes and other worldwide environmental issues have to be dealt with, through efficient international cooperation. In this context, proper food production and supply as well as correct and balanced diets for all, closely associated to a new ecological vision of development based on sustainability principles are crucial. The adoption of sustainable food systems and diets in their broadest and comprehensive meaning should be the right way to go. They should include a revision of the current development model and related food trade liberalization policies. Sustainable food policies should consider, in a coherent manner, both agriculture and the health sector, as well as new challenges represented by ageing, globalization and urbanization, with the aim to ultimately benefit agriculture, human health and the environment. To be really effective, these policies should be more locally based, self-reliant food economies in which sustainable food production, processing, distribution and consumption are integrated to enhance economic, environmental and social health (Kearney, 2010). Apart from the need to better assemble and recompose the conceptual aspects connected to sustainable food systems and diets, their transposition in practice through helpful and replicable models is essential. The Mediterranean diets, for their intrinsic characteristics can represent valid models to address the main issues concerning the sustainable food system worldwide.

References

Alexandratos, N. (2006). The Mediterranean diet in a world context. Public Health Nutrition: 9(1A), 111–117.

American Dietetic Association (2007). Position of the American Dietetic Association: Food and Nutrition Professionals Can Implement Practices to Conserve Natural Resources and Support Ecological Sustainability. J Am Diet Assoc, 107, 1033–1043.

American Public Health Association (2007). Toward a Healthy, Sustainable Food System. American Public Health Association, Policy Statement 200712. Washington, DC: APHA. Retrieved 15 may 2011 from: http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1361

Bioversity International, (2009). Neglected and Underutilized Species - Overview. Retrieved 15 may 2011 from: http://www.bioversityinternational.org/scientific_information/themes/neglected_and_underutilized_species/overview.html.

Burlingame, B., Charrondiere, R., Mouillè, B. (2009). Food composition is fundamental to the cross-cutting initiative on biodiversity for food and nutrition. Journal of Food Composition and Analysis 22, 361–365.

Capatti, A., Montanari, M., O'Healy, A. (2003) - Italian cuisine: a cultural history - Columbia University Press, 2003 - 348 pages

Conway, G. (1997). The Doubly Green Revolution: Food for All in the Twenty-First Century. Penguin, London.

De Onis, M., Blössner, M., Borghi E. (2010). Global prevalence and trends of overweight and obesity among preschool children. Am J Clin Nutr 92, 1257–64.

European Commission (2010). Communication from the Commission to the European parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Europe 2020 Innovative Flagship Initiative - Innovation Union. SEC (2010) 1161 – COM (2010) 546 final

European Commission (2011). Green paper "From Challenges to Opportunities: Towards a Common Strategic Framework for EU Research and Innovation funding". COM(2011) 48 Final

FAO (2009). The State of Food Insecurity in the World. FAO, Rome. Retrieved January 2011 from: http://www.fao.org/docrep/012/i0876e/i0876e00.HTM.

FAO (2010). International Symposium on Food-based Approach for Improving Diets and Raising Levels of Nutrition. FAO, Rome, 7-9 December 2010

Harlan, J.R. (1975). Crop and man. American Society of Agronomy and Crop Science Society of America, Madison.

International Assessment of Agricultural Knowledge, Science and Technology for Development - IAASTD (2008). Global Summary for Decision Makers Retrieved 12 May 2010 from: http://www.agassessment.org/docs/Global_SDM_060608_English.htm.

Keys, A. and Keys, M. (1959) - Eat well & stay well; foreword by Paul Dudley White, M.D Garden City, N.Y., Doubleday & C., 1959.

Kearney, J. (2010). Food consumption trends and drivers. Philos Trans R Soc Lond B Biol Sci. 365(1554), 2793-2807.

Lund Declaration (2009) issued in July 2009. Retrieved 16 May 2011 from: http://www.epsoweb.org/news/lund-declaration

Leonti, M., Nebel, S., Rivera, D., Heinrich, M. (2006). Wild gathered food plants in the European Mediterranean: a comparative analysis. Economic Botany 60, 130-142.

Molden, D. (Ed.) (2007). Water for Food, Water for Life. A Comprehensive Assessment of Water Management in Agriculture. Earthscan, London. Retrieved 12 May 2010 from: http://www.iwmi.cgiar.org/assessment/Publications/books.ht.

Murrieta, R. S. S., Dufour, D.L, Siqueira, A. D. (1999). Food Consumption and Subsistence in Three Caboclo Populations on Marajó Island, Amazonia, Brazil. Human Ecology, 27(3), 455-475.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature 403, 853-858.

Nestlè, M. (2006). What to eat? North Point Press, NY.

Pasta S., Garfì G., La Bella F., Rühl J., Carimi F. (2011). An Overview on the Human Exploitation of Sicilian Native Edible Plants. In: Davis RE (Ed.), Wild Plants: Identification, Uses and Conservation. Nova Science Publishers, New York. In press.

Pieroni, A., Nebel, S., Santoro, R. F., Heinrich, M. (2005). Food for two seasons: culinary uses of non-cultivated local vegetables and mushrooms in a south Italian village, Int. J. Food Sci. and Nutr. 56, 245–272.

Pimentel, D., & Pimentel, M. (2008). Food, Energy, and Society. 3rd ed. CRC Press, Boca Raton, FL.

Polanyi, M. (1958). Personal Knowledge: Towards a Post-Critical Philosophy,Routledge & Kegan Paul Ltd, London.

Pollan, M. (2010). Food Rules: An Eater's Manual. New York, Penguin Press.

Schechter, M. (2004). Conviviality, gender and love stories: Plato's symposium and Isak Dinesen's (K. Blixen's) Babette's feast. Trans, Internet Journal for Cultural Sciences, No. 15.

Serra-Majem, L., Bach, A. and Roman, B. (2006). Foreword. Recognition of the Mediterranean diet: going at the step further. Public Health Nutrition: 9(1A), 101–102.

Shiva, V. (2002). The Violence of the Green Revolution. Zed Books, New York, USA.

Sustainable Development Commission (2009). Food security and sustainability- the Perfect Fit. Position paper UK Government 2009. Retrieved 12 May 2010 from: http://www.sd-commission.org.uk/presslist.php/101/sdc-stop-decline-in-uk-food-production.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., Polasky, S. (2002). Agricultural sustainability and intensive production practices. Nature 418, 671–677.

Tripp, R., van der Heide, W. (1996). The erosion of crop genetic diversity: Challenges, strategies and uncertainties. Natural Resource Perspectives, No 7, March 1996. London: ODI.

Turner, N. J., Łuczaj, Ł. J., Migliorini, P., Pieroni, A., Dreon, A. L., Sacchetti, L. E., Paoletti, M. G. (2011). Edible and Tended Wild Plants, Traditional Ecological Knowledge and Agroecology, Critical Reviews in Plant Sciences, 30(1), 198-225.

UN (2010). Report submitted by the Special Rapporteur on the right to food, Olivier De Schutter. General Assembly, Human Rights Council, Sixteenth session, GE.10-17849 A/HRC/16/49 20 December 2010.

UNEP (2009). The environmental food crisis the environment's role in averting future food crises a UNEP rapid response assessment. UNEP, GRID-Arendal, Retrieved 12 May 2010 from: http://www.grida.no/publications/rr/food-crisis.

van de Wouw, M., van Hintum, T., Kik, C., van Treuren, R., Visser, B. (2009). Genetic erosion in crops: concept, research results and challenges. Plant Genet Resour Charact Util 8(1), 1-15.

Vigouroux, Y., Barnaud, A., Scarcelli, N., Thuillet, A.C. (2011). Biodiversity, evolution and adaptation of cultivated crops. Comptes Rendus Biol. In press.

Worldwatch Institute (2011). The State Of The World: Innovations that Nourish the Planet. W. W. Norton & Company, Inc., New York, N.Y. ISBN 978-0-393-33880-5.

FOOD AND ENERGY: A SUSTAINABLE APPROACH

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Abstract
The question of food production implies social, ethical, economic and environmental aspects that in recent times have become increasingly important and relevant. The global food production heavily relies on fossil resources, among which the most important is oil. Up to now, the modern food system has been based on the assumption of an unrestricted availability of low-cost fossil resources. Moreover, its expansion contributes to global warming due to the emission of greenhouse gases.
From an energy efficiency standpoint, the modern food system is the least effective industrial system: it consumes more energy than it produces. A study on the environmental impact of the products and services used in the EU-25 has evidenced how the food and drink, tobacco and narcotics are collectively responsible for 22–31 percent of the global warming. Recently, owing to problems linked to the food system sustainability, it was considered how changes in lifestyles could influence greenhouse gas emissions. Consumer choices could play a leading role. Dietary choices could give their contribution not only to health, but also to the sustainability of the agricultural system. In recent years, some indicators were developed in order to evaluate the environmental performance of food production systems like food miles and Life-Cycle Assessment (LCA) of the food supply chain. The challenge is to develop and exploit the tools necessary to better understand the sustainability of food chains, optimize sustainable primary production and identify consumer attitudes towards sustainable food production. In this context, the Mediterranean diet would represent a key resource for sustainable development around the Mediterranean Basin and worldwide. The diet is grounded in respect for the environment and biodiversity, and ensures the preservation and development of traditional activities and crafts related to the fishing and farming communities.

The energy issue
The continuing world population growth, rapid economic development (even if interspersed with periods of stagnation and recession) and – above all – the request of emerging countries to benefit from the economic boost, inevitably imply the need for greater energy requirements. Global food production heavily relies on fossil resources, among which the most important is oil. As a consequence, every threat to the regular supply of oil is a threat to food security, that is to the availability of and access to safe food, adequate for a nutrient diet. Our modern agro-industrial food system is comparable to the other industrial systems for its complex structure and the amount of energy used. Furthermore, it can also be considered as part of the same industrial economic system which is traditionally thought to operate like a bubble floating in the space, benefiting from an unlimited supply of natural resources, bolstering economic activities and pouring waste in the environment. The environment is therefore the only one to pay, in the form of waste, the environmental costs of the entire economic system.
Up to now, the modern food system has been based on the assumption of an unrestricted availability of low-cost fossil resources. Moreover, its expansion contributes to global warming due to the emission of greenhouse gases. As Herman E. Daly has asserted for a long time, modern economies must be considered as subsystems of larger ecosystems and have to function within those constraints. That is to say, modern economies must be able to manage limited resources and create sustainable development at the same time. The entire food system uses energy, both directly and indirectly, and depends on fossil resources: chemical industry products, mainly fertilizers and pesticides, farming machines and their fuel, energy for water supply and its distribution, for the transport of agricultural products, for their transformation and packaging and, finally, for the distribution to the final consumers. In the last century, in the western countries, the progress of genetics, mechanics and chemistry (the green revolution) as well as the low cost of energy, have determined the development of the food system, ensuring copious and good quality food production.

In the last 50 years, the global production of cereals tripled (from 631 million tonnes in 1950 to 2 029 million tonnes in 2004) and the current situation forces us to pay attention to the adoption of sustainable agricultural practices and natural resources (energy, climate, water, soil and biodiversity).

The energy efficiency of the food system

From an energy efficiency standpoint, the modern food system is one of the least effective industrial systems: it consumes more energy than it produces. One indicator of the unsustainability of the modern food system is the Sustainability Index (SI), the ratio of energy inputs (the energy required to produce a food divided by the energy content of a food product, evaluated in calories).

In the last century (1910–2010), this indicator has increased from close to 1 for traditional pre-industrial societies at the beginning of the last century to a value close to 9 in the 1970s, to arrive, today, to a value equal to, and sometimes higher than 100.

The food system and global warming

A study on the environmental impact of the products and services used in the EU-25 (cited in Moresi and Valentini, 2010) has evidenced how the food and drink, tobacco and narcotics are collectively responsible for 22–31 percent of global warming. Among these products, meat and meat products have the largest environmental impact of the total consumption, their estimated contribution to global warming (GWP[1]) being close to 12%, 24% of Eutrophication Potential (EP[2]) and 10% of Photochemical Ozone creation potentials (PCOP[3]). Dairy products contribute some 5% to GWP, some 10% to EP and some 4% to PCOP. Cereal products (bread, pasta, flours) contribute some more 1% to GWP and PCOP, and close to 9% to EP. Finally, fruits and vegetables (including frozen ones) give a contribution close to 2% to GWP, EP and PCOP.

Consumer choices

Consumer choices could play a leading role. In 1986, J. Gussow and K. Clancy introduced the term "sustainable diet": dietary choices could give their contribution not only to health, but also to the sustainability of the agricultural system. Their studies showed the strong link that exists between dietary choices and land use and conservation, water management and energy resources. Recently, owing to problems linked to the food system sustainability, it was considered how changes in lifestyles could influence greenhouse gas emissions. In the United Kingdom, it has been calculated that the CO2e emissions per capita due to dairy products and meats consumption equal 2 194 kg CO2e, whereas those due to vegetable products consumption (cereals, fruits and vegetables) correspond to 450 kg CO2e. A diet with a 30% decrease in animal products and a 15% increase in vegetables would allow a reduction of emissions of 590 kg CO2e per capita per year. This reduction would be equivalent to a total decrease of 5% of the global emissions per capita, equal to 10.3 Mg CO2e expected in 2008. Dietary choices aimed at reducing CO2e emissions must however be formulated guaranteeing nutritionally balanced menus.

Sustainability indicators

In recent years, some indicators were developed in

[1] Global warming potential (GWP) is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. The global warming potential is calculated in carbon dioxide equivalents (CO2-Eq.). This means that the greenhouse potential of an emission is given in relation to CO2. Since the residence time of the gases in the atmosphere is incorporated into the calculation, a time range for the assessment must also be specified. A period of 100 years is customary.

[2] Eutrophication Potential (EP): Eutrophication is the enrichment of nutrients in a certain place. Eutrophication can be aquatic or terrestrial. Air pollutants, waste water and fertilization in agriculture all contribute to eutrophication. The eutrophication potential is calculated in phosphate equivalents (PO4-Eq).

[3] Photochemical Ozone creation Potential (PCOP): photochemical ozone creation potential (POCP) is measured in ethylene-equivalents (C2H4-Eq.). Despite playing a protective role in the stratosphere, at ground-level ozone is classified as a damaging trace gas. Photochemical ozone production in the troposphere, also known as summer smog, is suspected to damage vegetation and material. High concentrations of ozone are toxic to humans.

order to evaluate the environmental performance of food production systems. In the 1990s, Tim Lang (Professor of Food Policy, City University, London) coined the term "food miles". Food miles is a term that refers to the distance that a food item travels from the place where it is produced to the place where it is eaten. The idea behind food miles was to highlight the hidden ecological, social and economic consequences of food production to consumers in a simple way. In recent years, food miles have increased very rapidly. Between 1978 and 2002, the amount of food trucked increased by 23 percent. And the distance for each trip increased by over 50 percent. In 2002, food transport accounted for an estimated 30 billion vehicle kilometres. The original idea behind the food miles concept was that the distance that farm produce travelled before consumption was a good indicator of the amount of CO2 that had been emitted.

That idea has been seriously challenged, because transport accounts for only a very small proportion of the CO2 emissions from farm produce. In some cases, carbon emissions are much lower for items produced in tropical countries rather than in temperate countries. In other cases, emissions are much lower when they come from the most efficient source. Considering these limits, it seems more appropriate to consider how food is produced and with what kind of energy. A suitable strategy is the Life-Cycle Assessment (LCA) of the food supply chain. LCA is a methodology used for analysing and assessing the environmental impacts of a material, product or service throughout its entire life cycle, from the extraction of raw materials and their processing, through manufacturing, transport, use and final disposal: an analysis from cradle to grave. Recently, Life-Cycle Assessments have been utilized to evaluate and improve the environmental performance of food production systems. In order to find the possible directions to sustainable food production and consumption, LCA has been applied for more than 15 years to agricultural and food systems, identifying their environmental impacts throughout their life cycle and supporting environmental decision-making. A variety of databases and methodological approaches have been outlined over this period to support the applications of LCA to food systems. LCA results have been used in the development of eco-labelling criteria with the aim of informing consumers of the environmental characteristics of products. However, most analyses are limited to case studies of either a single food or a limited set of items. The challenge is to develop and exploit the tools necessary to better understand the sustainability of food chains, optimize sustainable primary production and identify consumer attitudes towards sustainable food production.

Mediterranean diet

The Mediterranean diet is an example of sustainable food production. It is a dietary pattern that can combine taste and health, environmental protection, biodiversity protection and consumption of local and seasonal products. The concept of a Mediterranean diet was developed for the first time in 1939, by Lorenzo Piroddi, a nutritionist who understood the connection between diet and diabetes, bulimia and obesity, as confirmed by the studies conducted by Ancel Keys and his school afterwards. The main features of the Mediterranean diet are:

- a high intake of vegetables, legumes, fruits, nuts and cereals, mostly wholemeal;
- the prevalence of the use of olive oil, compared with a modest intake of saturated fats;
- a moderate intake of fish, also as a function of distance from the sea;
- a regular but limited intake of dairy products (mainly in the form of yogurt and cheese);
- a moderate consumption of meat and poultry;
- a moderate intake of ethanol and active ingredients such as resveratrol, mainly in the form of wine consumed during meals.

"The Mediterranean Diet is a set of skills, knowledge, practices and traditions that range from landscape to the table, including crops, harvesting, fishing, preservation, processing, preparation and, in particular, the consumption of food. [...]. However, the Mediterranean diet (from the Greek diaita, or lifestyle) is more than just a set of foods. It promotes social interaction, because the common meal is the basis of social customs and festivities shared by a given community, and resulted in a considerable body of knowledge, songs, maxims, tales and legends. The Diet is grounded in respect for the environment and biodiversity, and ensures the preservation and development of traditional activities and crafts related to the fishing and farming communities of the Mediterranean ". For these reasons, related to both nutritional and social, cultural and environmental aspects, on 17 November 2010 in Kenya, the Mediterranean diet was declared part of the intangible heritage of humanity by the Intergovernmental Committee of the Convention on intangible heritage of humanity of UNESCO. The characteristics of the diet can be graphically represented by the food pyramid, whose first version was drawn in 1992 by the United States Department of Agriculture. The food pyramid shows in a concise and effective way how to adopt a healthy and balanced type of diet. As part of Expo 2015, having the theme "Feeding the Planet, Energy for Life", among the project proposals is a proposal on the Mediterranean diet. The Expo will be an extraordinary international context in which to recognize and promote the Mediterranean diet as a key resource for sustainable development around the Mediterranean Basin and worldwide. The ability to inspire through food a sense of continuity and identity for local people may represent, now and even more in the future, a factor of sustainable growth.

Conclusions

The current production of food in our society is extremely complex. This complexity has led to a gradual loss of knowledge and awareness on how the food that every day we put on our tables is produced and prepared. The question of food production implies social, ethical, economic and environmental aspects that in recent times have become increasingly important and relevant. Food, especially in a country like Italy, must regain its importance not only nutritionally but also socially. Significantly in this context is the consumer behaviour and the virtuous changes that it can promote in the food system. The inclusion of the Mediterranean diet into the intangible heritage of humankind by UNESCO and the project application on the Mediterranean diet as part of Expo 2015 are clear indications of a different way of looking at food production and nutrition. All of the above must be linked to the need to feed an increasing world population. The global governance could achieve the necessary objectives: 1. increase international trade in order to balance the surplus production in OECD, former Soviet and South American countries with Asian and African deficits; 2. increase agricultural production, adopting technological and organizational progresses that promote sustainability; 3. change consumption patterns, starting from developed countries, aiming at a consumption of about 2 000 kilocalories per day (of which only 500 kilocalories derived from animals) and reducing waste (presently, 800 kilocalories per day go in the garbage); 4. reduce the bioaccumulation of toxic substances within food matrices, through a mapping of the major sources of pollution. If international policies to promote better nutrition are successful, rich countries will experience reduced diseases from overweight and a diet that is more environmentally sustainable. If governments manage to agree on a stable trading system to compensate the deficit and the surplus food production in the different parts of the world, a structural problem of social injustices on the planet will be healed, reducing now evident social tensions. If science and technology once again do their job, the quantity and quality of food production will make a leap forward. Everyone should do his part and then the world of tomorrow will be fairer and more virtuous than that of today in terms of food security.

References

Barclay C. (2010) Food Miles Standard Note SN/SC/4984 Science and Environment Section House of Commons Library UK

Clancy K., Gussow J.(1986) Dietary guidelines for sustainability. Journal of nutrition Education 18, 1-5, USA.

Daly H.E. (1999) Ecological Economics and the Ecology of Economics Northampton, Mass: Edward Elgar, Maryland, USA.

"La Dieta Mediterranea è patrimonio immateriale dell'Umanità" (17-11-2010), website references http://www.unesco.it/cni/index.php/news/174-la-dieta-mediterranea-e-patrimonio-immateriale-dellumanita.

Moresi M., Valentini R. (2010), "Dieta mediterranea e impatto ambientale", Rivista Industrie Alimentari XLIX, maggio, 9-20, Chirotti Editore, Torino.

Pirrodi L. (1993). "Cucina Mediterranea. Ingredienti, principi dietetici e ricette al sapore di sole", Mondadori, Milano.

DOUBLE PYRAMID: HEALTHY FOOD FOR PEOPLE AND SUSTAINABLE FOR THE PLANET

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Abstract

Man has long been aware that correct nutrition is essential to health. Development and modernization have made available to an increasing number of people a varied and abundant supply of foods.

Without a proper cultural foundation or clear nutritional guidelines that can be applied and easily followed on a daily basis, individuals risk following unbalanced – if not actually incorrect – eating habits. Proof of this is the recent, prolific spread of pathologies caused by overeating and accompanying reduction in physical activity (including obesity, diabetes and cardiovascular disease) in all age brackets of the population, including children and young people.

The Mediterranean diet, recognized by UNESCO in 2010 as an "Intangible Cultural Heritage" and internationally recognized as a complete and balanced diet pattern, proves to be a sustainable model for the environment.

The Barilla Center for Food & Nutrition is offering the Food Pyramid in a double version, positioning foods not only following the criteria nutritional science has long recommended on the basis of their positive impact on health, but also in terms of their impact on the environment. The result is a "Double Pyramid": the familiar Food Pyramid and an environmental Food Pyramid. The latter, placed alongside the Food Pyramid, is shown upside-down: foods with higher environmental impact are at the top and those with reduced impact are at the bottom. From this "Double Pyramid" it can be seen that those foods with higher recommended consumption levels, are also those with lower environmental impact. Contrarily, those foods with lower recommended consumption levels are also those with higher environmental impact. In other words, this newly-elaborated version of the Food Pyramid illustrates, in a unified model, the connection between two different but highly-relevant goals: health and environmental protection.

The Environmental Pyramid was constructed on the basis of the environmental impact associated with each food estimated on the basis of the Life Cycle Assessment (LCA), an objective method for evaluating energy and environmental impact for a given process (whether an activity or product). More specifically, process assessment underscores the extent to which the main environmental impacts are seen in the generation of greenhouse gas (Carbon Footprint), consumption of water resources (Water Footprint) and Ecological Footprint "land use". In order to provide a more complete and effective communications tool, only the Ecological Footprint was used as a reference index in creating the Environmental Pyramid.

This work, far from being conclusive, aims to encourage the publication of further studies on the measurement of environmental impacts of food, which will be considered in future editions of this document.

In this sense the most innovative element of the updated Double Pyramid is represented by its coherence with the needs of those who are still growing. Since food needs during the age of development differ from those of adults, it was decided to design a specific nutritional pyramid. The same approach used to design the "adult version" of the pyramid was employed to realize the "Double Pyramid for those who are still growing" and its environmental impact has been calculated according to the same criteria.

The objective is to increase the coverage of statistical data and examine the influence that may have some factors, such as, for example, geographical origin or food preservation.

Finally the technical aspects, data and considerations are highly summarized in order to provide proper scientific information and conclusions. The technical document, on the contrary, is for "experts only" and presents detailed data and elaborations

1. The Food Pyramid model

The Pyramid was created using the most current nutrition research to represent a healthy, traditional

Mediterranean diet. It was based on the dietary traditions of Crete, Greece and southern Italy in the 1960s at a time when the rates of chronic disease among populations there were among the lowest in the world. From the first "Seven Countries Study" to the current days, many other studies have analysed the characteristics and the relationships between dietary habits adopted and the onset of chronic disease. Starting in the 1990s, there has also developed a line of study into the relationship between diet and longevity. In general, what emerges is that the adoption of a Mediterranean, or similar, diet, provides a protective factor against the most widespread chronic diseases. In other words, high consumption of vegetables, legumes, fruits and nuts, olive oil and grains (which in the past were prevalently wholemeal); moderate consumption of fish and dairy products (especially cheese and yoghurt) and wine; low consumption of red meat, white meat and saturated fatty acids. The interest of the scientific and medical community in the Mediterranean diet is still extremely active, and, in fact, the current specialist literature often publishes information about the relationship between Mediterranean-style dietary habits and the impact on human health. The beneficial aspects of the Mediterranean diet are backed by increasing evidence in terms of both prevention and clinical improvement regarding specific pathology areas. These publications present the results of clinical or epidemiological research in which adherence to the Mediterranean diet translates into measurable benefits in numerous areas of human health, which include, for example, cardiovascular disease, metabolic conditions, neurological or psychiatric pathologies (e.g. Alzheimer's), respiratory disease or allergies, female and male sexual disorders (e.g. erectile dysfunction) and certain oncological

FOOD PYRAMID

pathologies. In terms of this last point, of particular interest are the recent conclusions of a broad-ranging EPIC European study which examined 485 044 adults over the course of nine years; EPIC showed that increased adherence to the Mediterranean diet is connected to a significant reduction (-33%) in the risk of developing gastric cancer. Finally, it is interesting to note that the scientific literature demonstrates a positive impact of the Mediterranean diet across all age brackets, starting from pre-natal to childhood, adulthood and old age.

Its adoption is especially pronounced in the more educated segments of the population (not Europe only) which, moreover, it perceived consistency with the current sociocultural trends, such as attention to the welfare, the fight against obesity, the promotion of typical products, the search for natural products and natural attention to environmental protection.

The value of the Food Pyramid is twofold: first it is an excellent summary of the main knowledge gained from studies on medicine and nutrition, essential for anyone who pays attention to their health, second it is a powerful tool for consumer education, thanks also to its effective graphic form and its undoubted simplicity, it plays an important promotional role for the benefit of all those foods (fruits and vegetables in particular) that are almost always “unbranded” and not advertised by manufacturers.

2. The environmental impact of food production and Double Pyramids

The estimated environmental impact for each single food item was calculated on the basis of the information and public data which was measured through the Life Cycle Assessment (LCA): an objective assessment methodology to detect energy and environmental loads in a process (either an activity or a service). This kind of assessment includes the analysis of the whole value chain, starting from growing or extraction practices, raw material processing, manufacturing, packaging, transportation, distribution, use, re-use, recycling and final disposal. On the one hand, the LCA approach has the advantage of offering a fairly objective and complete assessment of the system; on the other hand, the disadvantage lies in a difficult transmission of the resulting complex outcome.

Synthetic indicators are then used to fully understand this outcome. These indicators are meant to preserve the scientific basis of the analysis as much as possible; they are selected according to the kind of system analysed and must simply and correctly represent the relations with the main environmental categories. The process analysis, more specifically and focusing our attention on food production, highlights the main environmental loads: greenhouse gas generation, the use of water resources and the ability to regenerate local resources. According to this input, and considering this work’s aim to provide valid results in an initial analysis, the following environmental indicators were chosen:

- **Carbon Footprint**, representing and identifying greenhouse gas emissions responsible for climate change: measured through the CO2 equivalent. By “Carbon Footprint” is meant the impact associated with a product (or service) in terms of emission of carbon dioxide equivalent (CO2-equiv), calculated throughout the entire life cycle of the system under examination. It is a new term utilized to indicate the so called Global Warming Potential (GWP) and, therefore, the potential greenhouse effect of a system calculated using the LCA – Life Cycle Assessment method.

In calculating the Carbon Footprint are always taken into consideration the emissions of all greenhouse gases, which are then converted into CO2 equivalent using the international parameters set by the Intergovernmental Panel on Climate Change (IPCC), a body operating under the aegis of the United Nations. Correctly calculating the Carbon Footprint of a good or service must necessarily take into account all the phases of the supply chain starting with the extraction of the raw materials up through disposal of the waste generated by the system on the basis of LCA methodology. Clearly, this requires the creation of a "working model" that can fully represent the supply chain in order to take into account all aspects which actually contribute to the formation of the GWP.

- **Water Footprint** or virtual water content, measures the use of water resources in terms of volume (expressed in m3) of water consumed and/or polluted by the entire chain – from production to direct consumption of goods/services.

The indicator is closely linked to the concept of virtual water (virtual water), theorized in 1993 by Professor John Anthony Allan of King's College London School of Oriental and African Studies, which indicates the volume of freshwater consumed to produce a product (a commodity, good or service) by summing all phases of the production chain. The term "virtual" refers to the fact that the vast majority of water used to produce the product is not physically contained in the same product, but has been consumed during its entire life cycle.

The methodology used for the measurement of the indicator was developed by the Water Footprint Network (www.waterfootprint.org), a non-profit organization of reference that operates at international level to standardize the calculation and use of this impact indicator. According to the protocol published in a version updated in 2011, the Water Footprint of a system is the sum of three specific components both geographically and in terms of time and which corresponds to a different impact on the environment.

Component	Description
Green water	Volume of rainwater evapotranspired from the ground and cultivated vegetation.
Blue water	Volume of freshwater, which originated from surface or groundwater sources, used throughout the entire chain under observation that is not repleneshed into the basin or origin. This footprint includes both irrigation and process water consumption.
Grey water	Voume of polluted water associated with the production of goods or services measured as the amount of water (theoretically) required to dilute the pollutants to a degree as to ensure the quality of the water.

When looking at the details of agrifood chains, the most characteristic item, but also the most complex to evaluate, is the green water component given its close ties to the local climatic conditions and species cultivated as well as its productive yield. This component is particularly important for agricultural cultivations (it encompasses plant transpiration and other forms of evaporation). The following formula is used to calculate green water:

$$\text{Green water} \left[\frac{l}{kg}\right] = \frac{ETO\ (mm) * Kc * 10}{\text{yeld} \left[\frac{t}{ha}\right]}$$

where:

- ET0 is a factor that represents the volume of rainwater and depends on local climatic characteristics;
- Kc depends on the plant species cultivated;
- Yield depends on the crop cultivated and climatic conditions of the cultivation area.

As one might easily suppose, the value of green water of a product can vary greatly both from region to region and from year to year, as much depends on the value of ET0. The availability of public databases and tools, made available by FAO (Food and Agriculture Organization of the United Nations), allows simple retrieval of the necessary factors for the calculation of this contribution.

The blue water component is represented by both the quantity of water used during industrial production and that consumed for irrigation in the agricultural phase.

Lastly, the evaluation of the grey water component takes into account both the characteristics of water released from the system and the natural conditions of the receiving body in which it is released.

- **Ecological Footprint**, measuring the quantity of biologically productive land (or sea) needed to provide resources and absorb the emissions produced

by a manufacturing system: measured in m2 or global hectares.
The Ecological Footprint is an indicator used to estimate the impact on the environment of a given population due to its consumption; it quantifies the total area of terrestrial and aquatic ecosystems required to provide in a sustainable manner all the resources utilized and to absorb (once again in a sustainable way) all the emissions produced. The Ecological Footprint measures the quantity of biologically productive land and water required to both provide the resources consumed and absorb the waste produced.

The calculation methodology is identified by the Global Footprint Network and includes the following components in the calculation:

- Energy Land, represents the forest area required to absorb the carbon dioxide produced by fossil fuel burning and power for the production of that good;
- Cropland, represents the area of cultivated land necessary for the production of food and other non-edible resources of plant origin (cereals, fruit, vegetables, tobacco, cotton etc.);
- Grazing Land, represents the area required to produce food and non-edible resources of animal origin (meat, milk, wool etc.);
- Forest Land, represents the land, either cultivated or wild,utilized for the production of wood-based products;
- Built-up Land, represents the land occupied for the construction of roads, homes and other infrastructures;
- Fishing Ground, represents the marine and fre shwater surface area required for fisheries.

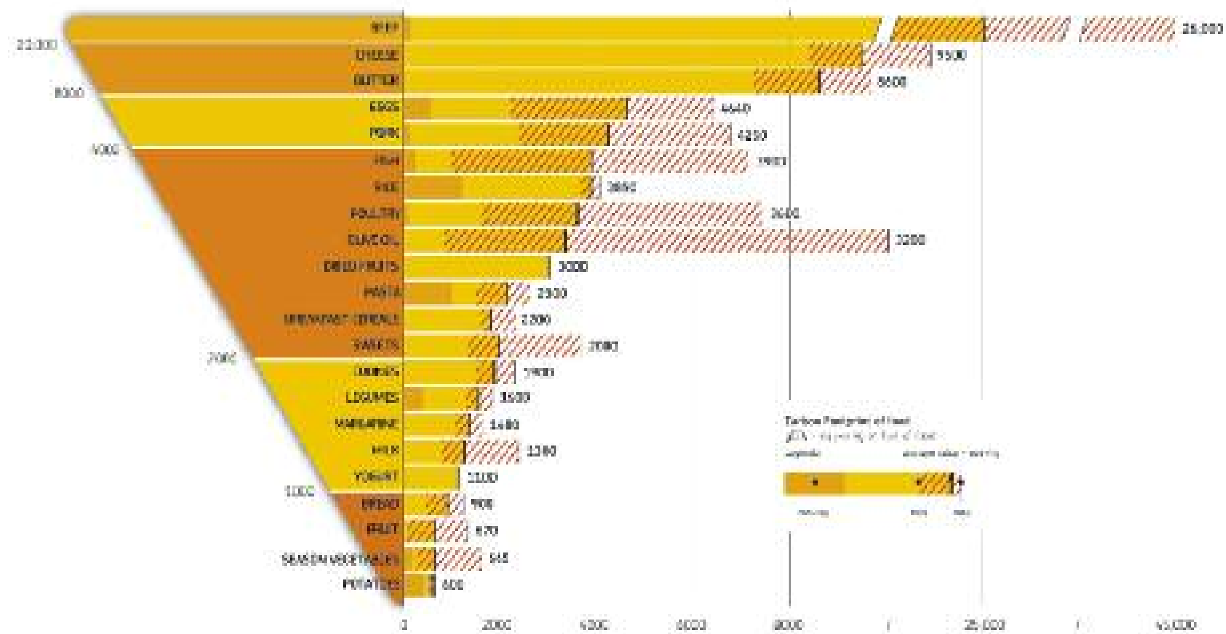
The Ecological Footprint is thus a composite indicator which, through conversion and specific equivalences, measures the various ways in which environmental resources are utilized through a single unit of measure, the global hectare (gha).

Global Footprint Network

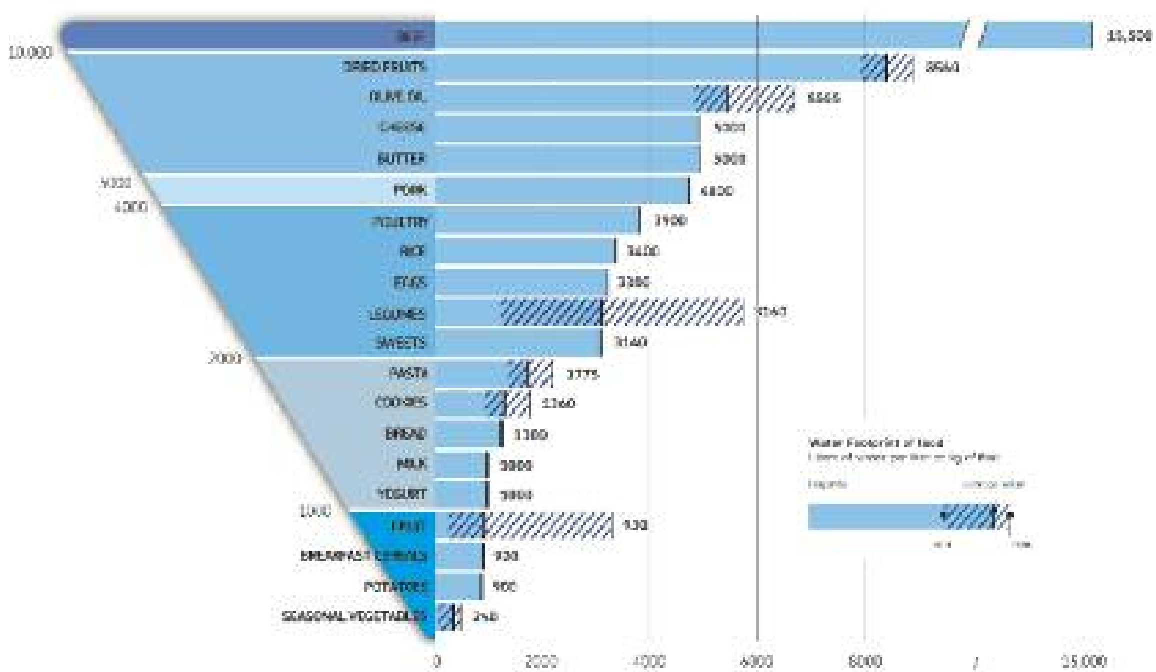
In 2004 Mathis Wackernagel and his associates founded the Global Footprint Network, a network of research istitutes, scientists and users of this indicator which aims to further improve its calculation method and bring it to higher standards, while at the same time guarantee enhanced scientific "robustness" for the indicator as well as promoting its spread.
Together with the Living Planet Index it represents one of the two indicators throught which, on a two-years basis, the WWF in collaboration with the Global Footprint Network and the Zoological Society of London, assesses the conservation status of the planet: the results are presented in the Living Plant Report.

It is, nevertheless, important to notice that the impacts this research takes into consideration are not just the ones generated by a food production chain; they can be the most relevant ones in terms of real impact and communication. Even though the environmental pyramid has been represented through the ecological footprint, for synthetic reasons the food environmental impact was measured by water and carbon footprint indicators, to avoid partial and sometimes misleading ideas of the phenomena. The pyramids concerning the three environmental impact indicators and the Environmental Pyramid are displayed below.

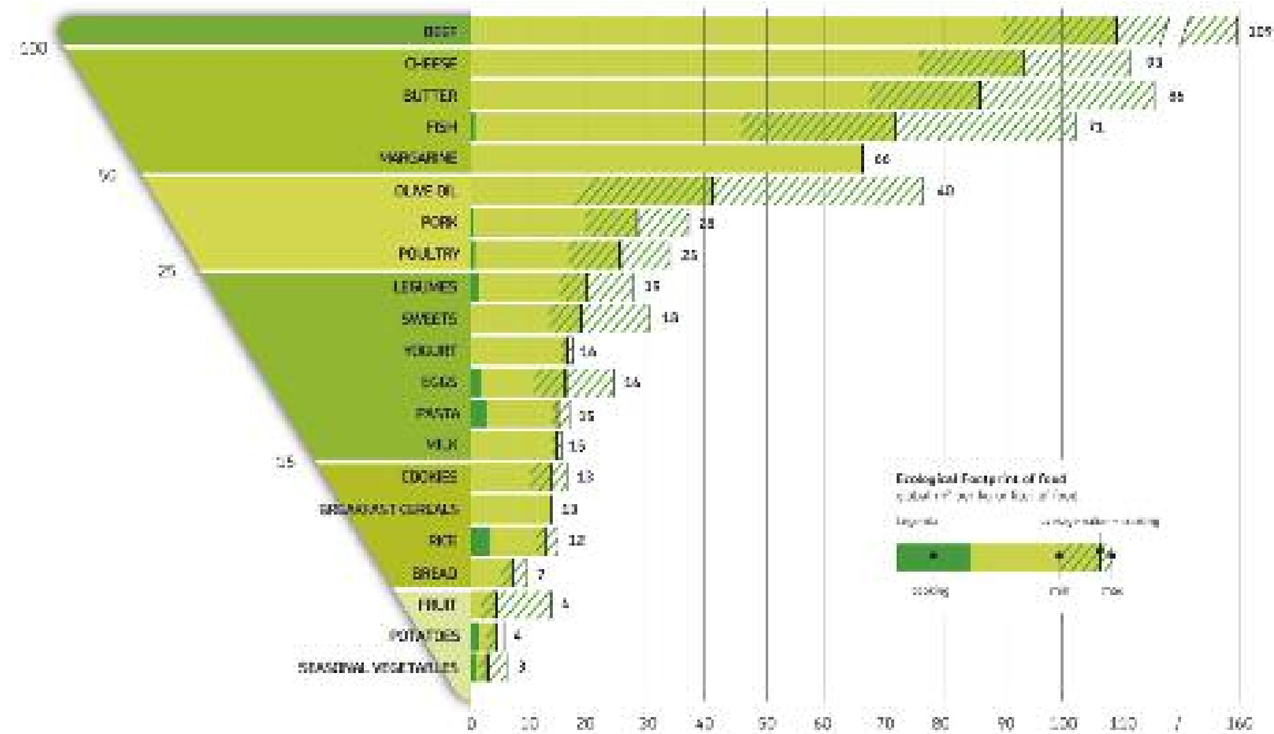
Carbon Footprint impact



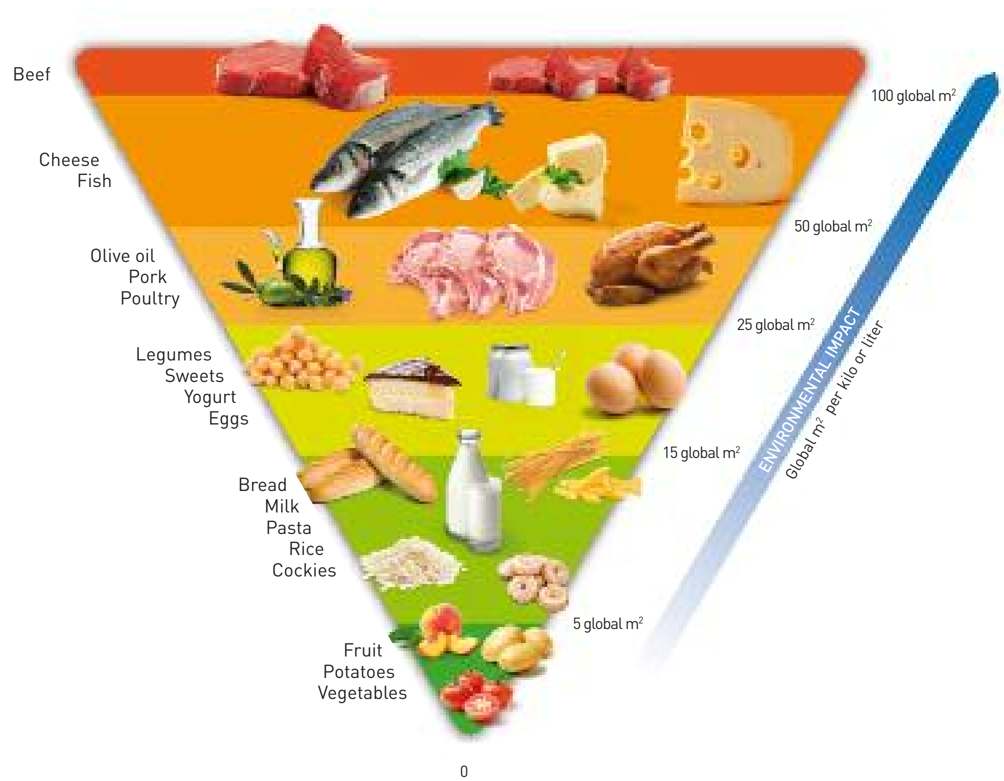
Water Footprint or virtual water content



Ecological Footprint

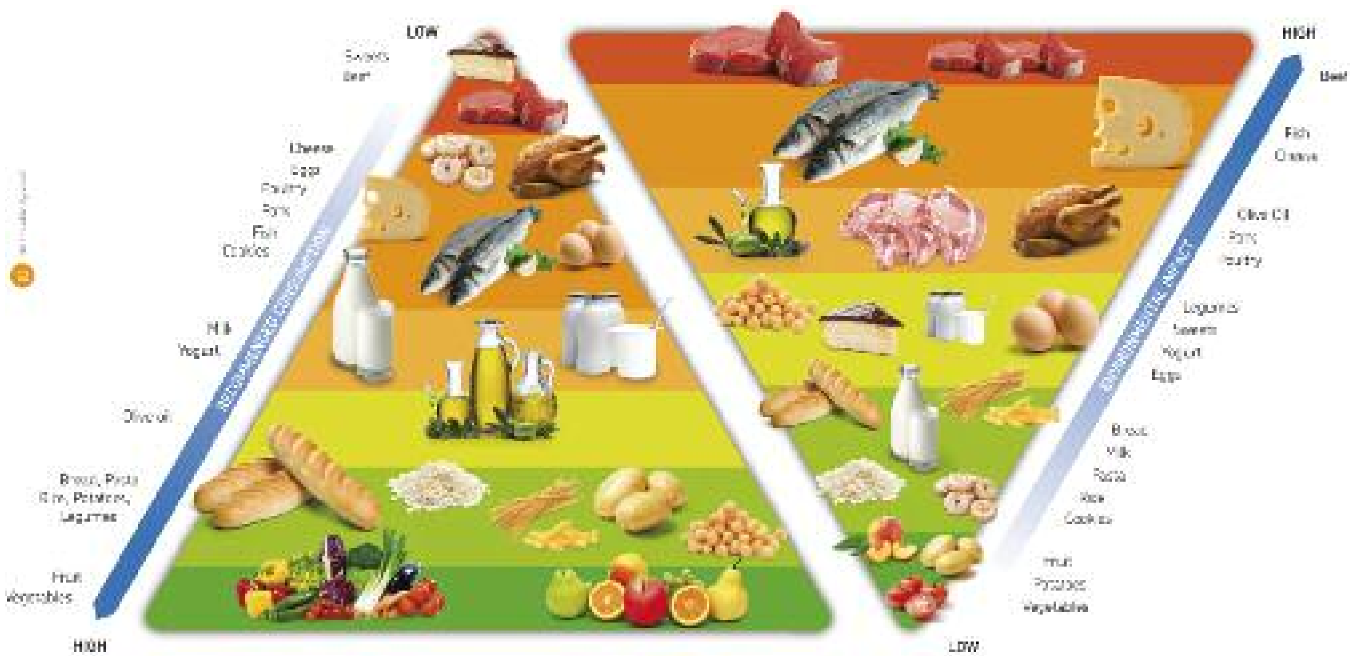


The BCFN environmental pyramid. Its layout is based on the re-classification of the foods' environmental impact, represented through their ecological footprints.



The Double Food-Environmental Pyramid is obtained by comparing the two pyramids (one in its correct position and the other one upside down). It is clear that, in general, the more recommended foods have a lower impact on the environment as well. Conversely, foods which are recommended for a lower consumption are also the ones that have the greatest impact on the environment.In practice, two different but equally relevant goals – people's health and environmental protection – fit into one single food model.

ENVIRONMENTAL PYRAMID



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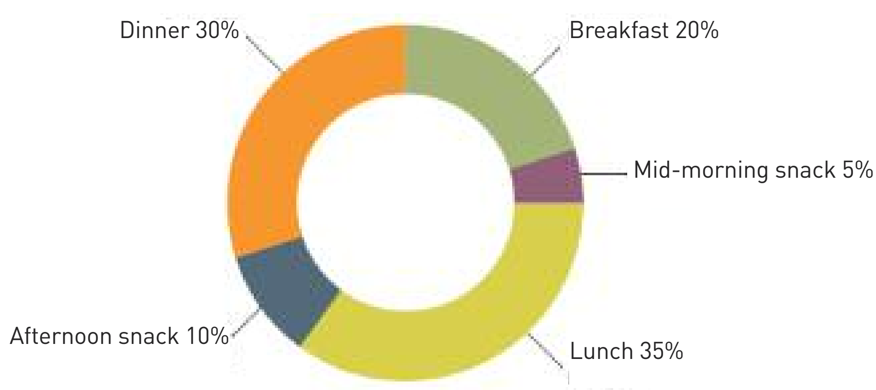
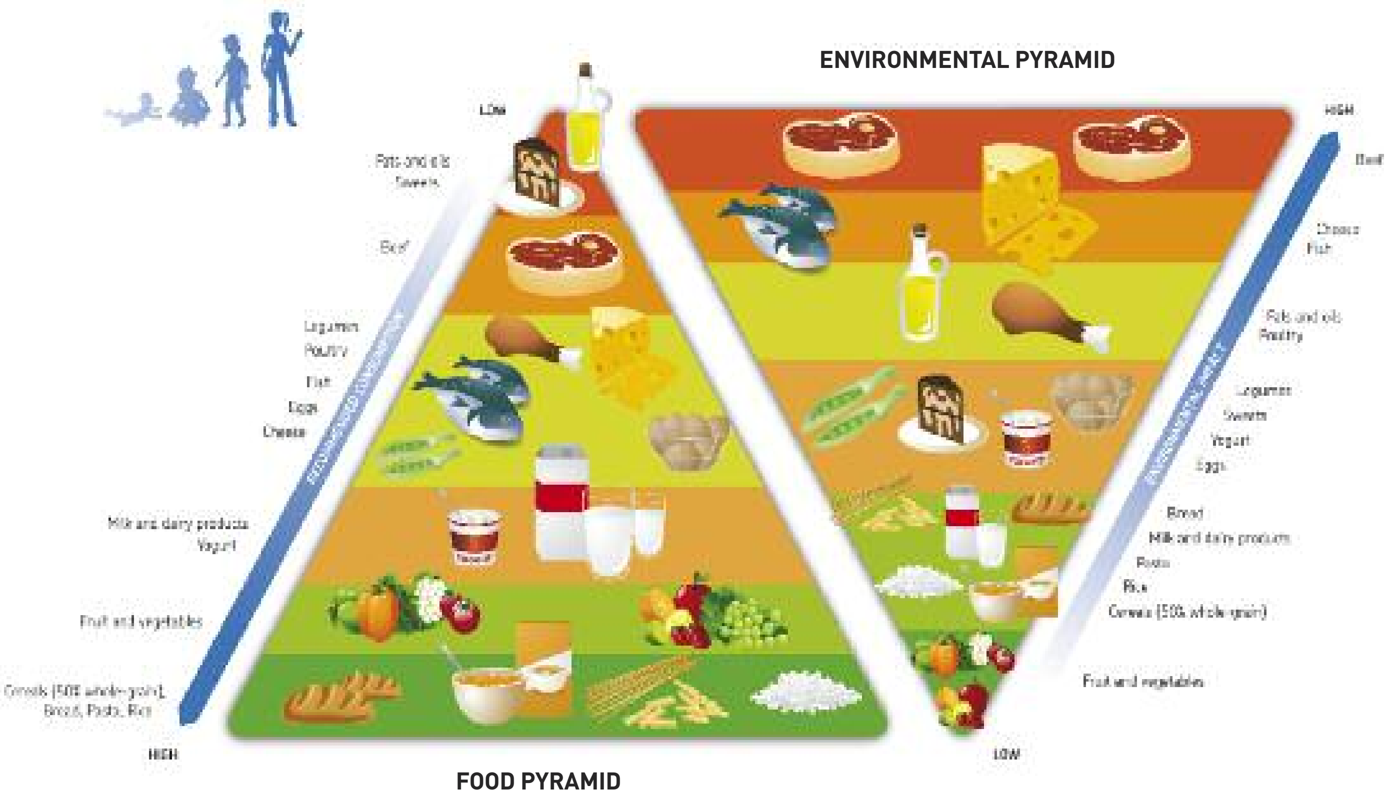
In the same way it has been developed the same concept for children and adolescents: if the main connections are changed between macro- and micronutrient intake and proper development at different stages of growth in an average diet which is adequate for meeting the requirements identified by pediatricians and nutritionists, it is possible to achieve the definition of a weekly composition of food eaten by children and adolescents that – as a whole – is both correct and balanced, in terms of type of food ingested and the distribution of daily calories.



Source The European House-Ambrosetti elaboration of data from the Italian Society of Human Nutrition

As in the case of adults, the diet of children and adolescents, too, should be based mainly on plant foods, particularly the various cereals, especially wholegrains, which are very important for their fibre content and protective components, and fruits and vegetables. Slightly above, we find milk and dairy products, preferably low-fat versions, as well as meat and fish; while higher up we get to products with a higher fat and sugar content, for which we suggest a relatively low frequency of consumption. The necessary intake of unsaturated fats should be covered by fish and dried fruit, preferably by using vegetable oils for condiments. The combination of an environmental and a nutritional pyramid for children has allowed us to create the BCFN Double Pyramid, dedicated to those who are growing.



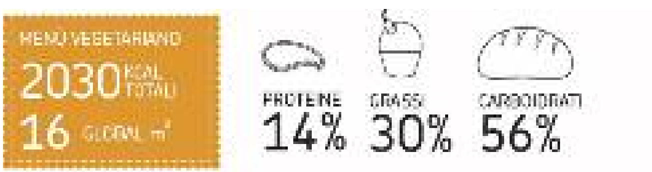
3. The impact of dietary habits

Using the ecological footprint – the indicator that was used for the Double Pyramid – as a point of reference, this chapter examines how the eating habits of people have an environmental impact. Significant reductions can be achieved both by changing eating habits (as demonstrated by some examples of menus) and by reducing waste.

According to recent statistics published by the Global Footprint Network (GFN), a citizen who lives in a country with a high income, in order to maintain the desired level of well-being, requires an ecological area of about 6.1 gha (1gha is approximately 170 square feet total per day), more than twice the global average (2.7 gha). Analysing the data in its components, one finds that food consumption is the first entry in terms of impact, with a significant Ecological Footprint totaling around 30–40 percent, which corresponds to about 1.8/2.4 gha per year. Referring to the average consumption (2.1 gha) and the reported daily impact, one can assume that every individual needs approximately 60 square meters to meet their global needs for food. The estimate takes into account the fact that, on average, a citizen who lives in a high-income country follows a diet of 2 650 kcal per day, considering the consumption of both food and drink, including food waste (unfortunately, a very common phenomenon). As an example, we can also

cite the case of the average Italian citizen, 42 square global metres exploited for food compared to 137 total, and that of a citizen of London with a global impact of 75 square metres out of 180. At this point, it is interesting to see to what extent the eating habits of individuals affect the Ecological Footprint.
In order to estimate the extent to which the food choices of individuals affect the Ecological Footprint, two different daily menus were analysed: both are balanced from anutritional point of view, both in terms of calories and nutrients (proteins, fats and carbohydrates), but in the first one, the protein is of plant origin ("vegetarian menu"), while in the second, it is mainly of animal origin ("meat menu"). The meat menu has an environmental impact that is two and a half times higher than the vegetarian one: 42 square global metres compared to 16; that is, a difference of at least 26, which represents a very significant share in the daily impact of an individual. Based on this data, we can hypothesize what the reduction of environmental impact of an individual might be if he or she simply changes eating habits.

Composition of a vegetarian menu and its environmental impact



Colazione	Spuntino	Pranzo
1 Porzione di frutta (200 gr) 4 Fette biscottate **1 global m²**	1 Vasetto di yogurt magro 1 Frutto **3 global m²**	1 Porzione pasta con finocchietto 1 Porzione di sformato di zucca e porri **4 global m²**

Spuntino	Cena
1 Vasetto di yogurt magro 1 Pacchetto di cracker non salati **1 global m²**	1 Porzione di verdure fagiolini (200 gr) e patate (400 gr) al vapore con scaglie di grana (40 gr) **7 global m²**

Composition of a meat menu and its environmental impact

Colazione	Spuntino	Pranzo
1 Tazza di latte parz. scremato 4 Biscotti **3 global m²**	1 Porzione di frutta (200 gr) **1 global m²**	1 Porzione di pizza Margherita Ortaggi misti crudi **16 global m²**

Spuntino	Cena
1 Vasetto di yogurt magro **2 global m²**	1 Porzione di minestra pasta e piselli 1 Bistecca di carne bovina alla griglia (150 gr) 1 Fetta di pane **20 global m²**

Fonte: BCFN, 2011

Variations in the ecological footprint depending on food choicesimpact

DIETA SETTIMANALE	IMPATTO SETTIMANALE [GLOBAL m2]	IMPATTO SETTIMANALE [GLOBAL m2]
7 VOLTE MENÙ DI CARNE	294	42
5 VOLTE MENÙ VEGETARIANO + 2 VOLTE MENÙ DI CARNE	164	23
7 VOLTE MENÙ VEGETARIANO	116	16

Fonte: elaborazione BCFN sulla base dei dati dell'Ecological Footprint Network.

Taking the example of a week's worth of food, we can hypothesize having three different diets on the basis of how many times a vegetarian menu is eaten and how many times the menu is based on meat: limiting animal protein to just twice a week, in line with the recommendations of nutritionists, you can "save" up to 20 square global meters per day.

Conclusions and suggestions for further research

The present study represents a further step in the investigation of the relationships between people's eating habits and food environmental impact. The analysis of main publicly available data lets us make some considerations about the impact on soil use (ecological footprint), water consumption (water footprint) and greenhouse gas emissions (carbon footprint) of foodstuffs included in the traditional food pyramid.

Indicators have been chosen in order to achieve the right balance between simplicity of the message to communicate and scientific rigour.

The most interesting result that emerges from the model is the strong correlation between environmental impact of foodstuffs and their nutritional characteristics. Specifically, it turns out that the foodstuffs of which we suggest a moderate consumption are also those that have a greater impact in terms of soil use, water consumption, and CO2 emissions. And vice versa.

In the future, in addition to the enlargement of the sample, that will enable the investigation of a higher number of product categories, two further limitations of the research have to be addressed. (a) the lack of references both to seasonality issues (considering that the environmental impact increases consistently when foodstuffs are consumed out of season) and (b) to logistics needed for transportation, with particular reference to the food cold chain. Therefore, further research by BFNC, that will be published in the third edition of the paper, will take into account data relative to the geographical variable in terms of both food production (i.e. origin) and place of consumption.

Bibliography

Nutrition

Barilla Center for Food and Nutrition "Double Pyramid: healthy food for people, sustainable food for the planet" – 2010

Barilla Center for Food and Nutrition "2011 Double Pyramid: Healty food for people, sustainable for the planet" - 2011

Butte, N .F. et al., Nutrient Intakes of US Infants, Toddlers and Preschoolers Meet or Exceed Dietary Reference Intakes, Baylor College of Medicine, Houston, TX, 2006.

De L orgeril, M . et al., Mediterranean Diet, Traditional Risk Factors, and the Rate of Cardiovascular Complications after Myocardial Infarction: Final Report of the Lyon Diet Heart Study, in "Explorations Fonctionnelles Cardiorespiratoires et Métaboliques", Saint-Etienne, 1999.

European Union, EU Platform on Diet Physical Activity on Health, 2005.

Ewing, B. et al., The Ecological Footprint Atlas 2010, Global Footprint Network, Oakland, CA, 2010.

Farchi, G . et al., Relationship Between Eating Patterns Meeting Recommendations and Subsequent Mortality in 20 Years, in "European Journal of Clinical Nutrition", # 49, pp. 408-419, 1995.

Fox, M .K. et. al., Food Consumption Patterns of Young Preschoolers: Are They Starting off on the Right Path?, Baylor College of Medicine, Houston, TX, 2010.

Frankel, S ., D .J. G unnel and T.J. P eters, Childhood Energy Intake and Adult Mortality from Cancer: The Body Orr Cohort Study, in "British M edical Journal", vol. cccxvii, n. 7155, A ugust 1998, p. 414.

Gonzalez-Gross, M . et al., The Healthy Lifestyle Guide Pyramid for Children and Adolescents, Universidad Politécnica de Madrid, Madrid, 2007.

Haskell, W .L. et al., Physical Activity & Public Health Updated Recommendations for Adults, American College of Sports Medicine & the American Heat Association, S tanford U niversity S chool of Medicine, Stanford, CA, 2007.

Huijbregts et al., Dietary Pattern and 20 Year Mortality in Elderly Men in Finland, Italy and the Netherlands, in "British Medical Journal", vol. CCCXV, # 7099, July 1997, p. 13.

International A gency for R esearch on Cancer, Weight Control and Physical Activity in Cancer Prevention, Lyon, 2002.

Istituto della S cienza dell'Alimentazione, La Piramide italiana dell'attività fisica, U niversità La Sapienza, Rome, 2005.

Kant, A .K. et al., A Prospective Study of Diet Quality and Mortality in Women, in "Journal of the American Medical A ssociation", # 283, pp. 2109-2115, 2000.

Keys, A . et al., Seven Countries. A Multivariate Analysis of Death and Coronary Heart Disease, Harvard University Press, Cambridge, MA/London, 1980.

Kouris-Blazos et al., Are the Advantages of the Mediterranean Diet Transferable to Other Populations? A Cohort Study in Melbourne, Australia, in "British Journal of Nutrition", # 82, 1999, pp. 57-61.

Lasheras, C., S . F ernandez e A .M. P atterson, Mediterranean Diet and Age with respect to Overall Survival in Institutionalized, Nonsmoking Elderly People, in "American Journal of Clinical N utrition", # 71, pp. 987-992, 2000.

Michels K.B. and A .A. W olk, A Prospective Study of Variety of Healthy Foods and Mortality in Women, in "International Journal of Epidemiology", A ugust 2002.

Must, A . and R .D. L ipman, Childhood Energy Intake and Cancer Mortality in Adulthood, in "Nutrition Reviews", vol. LVII , # 1, January 1999, pp. 21-24.

OMS R egional O ffice for E urope e UNI CEF, Feeding and Nutrition of Infants and Young Children, OMS Regional Publications, European Series, # 87, 2000 (updated reprint in 2003).

Osler, M . and M . S chroll, Diet and Mortality in a Cohort of Elderly People in a North European Community, in "International Journal of Epidemiology", # 26, pp. 155-159, 1997.

Osler, M . et al., Dietary Patterns and Mortality in Danish Men and Women: A Prospective Observational Study, in "British Journal of Nutrition", # 85, pp. 219-225, 2001.

Ramic, E . et al., Influence of Lifestyle on Overweight and Obesity in School-age Children, P rimary Health Care Center, Tuzla, 2008.

Scaglioni, S . et al., Early Macronutrient Intake and Overweight at Five Years of Age, in "International Journal of Obesity", # 24, pp. 777-781, 2000.

Trichopoulou et al., Diet and Overall Survival in Elderly People, in "British M edical Journal", vol. CCCXI, # 7018, Dicember 1995, pp. 1457-1460.

Victoria J. et al., Generation M2. Media in the Lives of 8- to 18-Year-olds, Kaiser F amily F oundation Study, January 2010.

World Health Organization (WHO), Global Strategy on Diet Physical Activity on Health, Geneva 2004.

Environmental

Baldo, G .L., M . M arino and S . R ossi, Analisi del ciclo di vita LCA, E dizioni A mbiente, M ilan, 2008 (new updated edition).

Barilla Center for F ood & N utrition, Doppia piramide: alimentazione sana per le persone, sostenibile per il pianeta, Parma, 2010.

Barilla Center for Food & Nutrition, Water Economy, Parma, 2011.

Baroni, L . et al., Evaluating the Environmental Impact of Various Dietary Patterns Combined with Different Food Production Systems, in "European Journal of Clinical Nutrition", 2006, pp. 1-8.

City L imits, A Resource Flow and Ecological Footprint Analysis of Greater London, Best Foot Forward, IWM (EB), 2002.

Ewing, B. et al., The Ecological Footprint Atlas 2010, Global Footprint Network, Oakland, CA, 2010.

Global F ootprint N etwork, Zoological Society of London, Living Planet Report 2010, WWF , Gland, 2010.

Hoekstra, A .Y., A .K. Chapagain, M .M. A ldaya and M .M. M ekonnen, The Water Footprint Assessment Manual: Setting the Global Standard, Earthscan, London, 2011.

Nikos, A . et al., World Agriculture: Towards 2030/2050 – Interim Report, Prospects for food, nutrition, agriculture and major commodity groups, Global Perspective Studies Unit, FAO , Rome, June 2006, pp. 3-8.

Segrè, A . and L . Falasconi, Il libro nero dello spreco alimentare in Italia, Edizioni Ambiente, Milan, 2011.

Tiezzi E., Tempi storici tempi biologici. Vent'anni dopo, Donzelli, Rome, 2001.

Allen, Pereira, Raes, Smith (1998), Crop Evapotranspiration - Guidelines for computing crop water requirements - Fao irrigation and Drainage Paper 56. Andersson K., 2000, LCA of Food Products and Production Systems, International Journal of LCA 5 (4) pp. 239 – 248; Andersson K., Ohlsson T., 1999,

Life Cycle Assessment of Bread Produced on Different Scales, International Journal of LCA pp. 25 – 40; Avraamides M., Fatta D., 2008

Resource consumption and emissions from olive oil production: a life cycle inventory case study in Cyprus, Journal of Cleaner Production 16 pp. 809-821; Bagliani M., Carechino M., Martini F., 2009,

La contabilità ambientale applicata alla produzione zootecnica, l'impronta ecologica dell'allevamento di bovini di razza piemontese, IRES (Istituto Ricerche Economico Sociali del Piemonte, Regione Piemonte, Collana ambiente 29;
Bagliani M., Contu S., Coscia I., Tiezzi E., "The evaluation of the Ecological Footprint of the Province of Siena (Italy)", in Tiezzi E., Brebbia C.A., Uso J.L. (eds.), "Ecosystems and Sustainable Development: Volume 1", pp. 387-396, Wessex Institute of Technology Press, Southampton (2003)

Baldo, Marino, Rossi, Analisi del Ciclo di Vita LCA, nuova edizione aggiornata, Edizione Ambiente;

Baroni L., Cenci L., Tettamanti M., Berati M., Evaluating the environmental impact of various dietary patterns combined with different food production systems, European Journal of Clinical Nutrition (2006), 1–8;

Basset-Mens, C. & van der Werf, H., 2003, Scenario-based environmental assessment of farming systems – the case of pig production in France, Agriculture, Ecosystems and Environment 1005, pp. 127-144;

Beccali M., Cellura M., Ludicello M., Mistretta M., Resource Consumption and Environmental Impacts of the Agrofood Sector: Life Cycle Assessment of Italian Citrus-Based Products, Environmental Management (2009) 43:707–724

Berlin, Environmental Life Cycle Assessment (LCA) of Swedish semi-hard cheese - International Dairy Journal 12 (2002) pp. 939– 953;

Best, Aaron, Stefan Giljum, Craig Simmons, Daniel Blobel, Kevin Lewis, Mark Hammer, Sandra Cavalieri, Stephan Lutter and Cathy Maguire. 2008. Potential of the Ecological Footprint for monitoring environmental impacts from natural resource use: Analysis of the potential of the Ecological Footprint and related assessment tools for use in the EU's Thematic Strategy on the Sustainable Use of Natural Resources. Report to the European Commission, DG Environment

Blengini GA, Busto M., The life cycle of rice: LCA of alternative agri-food chain management systems in Vercelli (Italy), Journal of environmental management (2008);

Busser S., Jungbluth N., 2009, The role of flexible packaging in the life cycle of coffee and butter, International Journal of LCA 14 (Suppl 1) pp. S80 – S91

Casey, J.W. & Holden, N.M., 2006, GHG emissions from conventional, agri-environmental and organic Irish suckler beef units, Journal of Environmental Quality 35, 231-239;

Casey, J.W. & Holden, N.M., 2006a, Quantification of GHG emissions from sucker-beef production in Ireland. Agricultural Systems 90, 79-98;

Cederberg C. & Darelius, K., 2000, Livscykelanalys (LCA) av nötkött - en studie av olika produktionsformer (Life Cycle Assessment (LCA) of beef – a study of different production forms, in Swedish), Naturresursforum, Landstinget Halland, Halmstad;

Cederberg C. & Darelius, K., 2001, Livscykelanalys (LCA) av griskött (Life Cycle Assessment (LCA) of pork, in Swedish), Naturresursforum Halland, Halmstad, Sweden;

Cederberg C. & Flysjö A., 2004, Environmental assessment of future pig farming systems – quantifi cation of three scenarios from the FOOD 21 synthesis work, SIK Report 723, SIK – The Swedish Institute for Food and Biotechnology, Göteborg, ISBN91-7290- 236-1;

Cederberg C. and Stadig M., 2003, System Expansion and Allocation in Life Cycle Assessment of Milk and Beef Production, International Journal of LCA 8 (6) pp. 350 -356;

Cederberg C., Berlin j., Henriksson M. & Davis, Jennifer, 2008, Utsläpp av växthusgaser I ett livscykelperspektiv för verksamheten vid livsmedelsföretaget Berte Qvarn (Emissions of greenhouse gases in a life cycle perspective from the food company Berte

Quarn, in Swedih), SIK-Report 777, ISBN 978-91-7290-270-1, SIK – The Swedish Institute for Food and Biotechnology, Göteborg, Sweden References 22;

Cederberg C., Meyer, D. & Flysjö, A., 2009a, Life Cycle Inventory of greenhouse gas emissions and use of land and energy of Brazilian beef exported to Europe, SIK-Rapport 792, SIK – Institutet för Livsmedel och Bioteknik, Göteborg, ISBN 978-91-7290-283-1;

Cederberg C., Sonesson, U., Davis, J. & Sund, V., 2009b, Greenhouse gas emissions from production of meat, milk and eggs in Sweden 1990 and 2005, SIK-Rapport 793, SIK – Institutet för Livsmedel och Bioteknik, Göteborg, ISBN 978-91-7290-284-8;
Cerelia, Dichiarazione ambientale di prodotto dell'acqua minerale naturale Cerelia imbottigliata in: PET da 1,5l e vetro da 1l, Rev.0 - Data: 30/07/2008, Registrazione N°: S-P-00123;

Chambers N., Simmons C., Wackernagel M., Sharing Nature's Interest, Ecological Footprints as an indicator of sustainability, Earthscan,2007, chapter 5, pp.79 – 105;

Colombo, "Manuale dell'Ingegnere"; 83° Edizione; Hoepli, 1997

Sitography

Global Footprint Network: www.footprintnetwork.org
La piramide alimentare italiana (The Italian food pyramid): www.piramideitaliana.it

The Greenhouse Gas Protocol: www.ghgprotocol.org
Water Footprint Network: www.waterfootprint.org26. Nikos, 2006.

Annex I

INTERNATIONAL SCIENTIFIC SYMPOSIUM
BIODIVERSITY AND SUSTAINABLE DIETS UNITED AGAINST HUNGER

FINAL DOCUMENT

3–5 NOVEMBER 2010
FAO HEADQUARTERS, ROME

DEFINITION OF SUSTAINABLE DIETS
Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.

PLATFORM FOR ACTION
1.The participants of the Symposium recommend that FAO, Bioversity International and the CBD Secretariat, in collaboration with other relevant organizations and institutions at international/regional/national/local level should establish a Task Force to promote and advance the concept of sustainable diets and the role of biodiversity within it, in the context of the CBD Cross-cutting Initiative on Biodiversity for Food and Nutrition, as contributions to the achievement of the MDGs and beyond.

2. FAO and Bioversity International should encourage the UN System, governments, international organizations, international food security and nutrition initiatives and other relevant bodies to finance and support research and development projects and programmes on biodiversity and sustainable diets.

3. Decision-makers should give priority to and promote sustainable diet concepts in policies and programmes in the agriculture, food, environment, trade, education and health sectors. Nutrition should be given more emphasis by plant and animal breeders and research on nutrient content of food biodiversity should be encouraged. Food composition data should be compiled by FAO in the INFOODS databases and by regional and national institutions.

4. New projects and case studies should be encouraged to demonstrate the synergies between biodiversity, nutrition and socio-economic, cultural and environment sustainability as well as to gather evidence about the potential of greater use of biodiversity for better nutrition and health and for poverty alleviation and improved livelihoods. The evidence gathered from these research efforts should be compiled by FAO and Bioversity International and made available on an open access web-based platform.

5. Food-based dietary guidelines and policies should give due consideration to sustainability when setting goals aimed at healthy nutrition. A guidance document on how to develop such guidelines and policies at national level could be elaborated by FAO, in collaboration with Bioversity International and other partners.

6. Governments, UN Agencies, civil society, research organizations and the private sector should collaborate in the development of programme activities and policies to promote sustainable diets in order to achieve sustainable food production, processing and consumption, and to minimize environmental degradation and biodiversity loss.

7. The development of a Code of Conduct for Sustainable Diets is strongly recommended.

INTERNATIONAL SCIENTIFIC SYMPOSIUM
BIODIVERSITY AND SUSTAINABLE DIETS UNITED AGAINST HUNGER

DRAFT PROPOSAL FOR A "CODE OF CONDUCT FOR SUSTAINABLE DIETS"

based on the model of the Code of Conduct for Marketing of Breast-milk Substitutes

CONTENTS INTRODUCTION

Article 1. Aim of the Code
Article 2. Scope of the Code
Article 3. Relationship with other international instruments
Article 4. Definitions
Article 5. Information and education
Article 6. Consumers
Article 7. Health Sector, Agriculture Sector, Environmental Sectors, Food Industry Sector
Article 8. Special Requirement of Developing Countries
Article 9. Research
Article 10. Implementation and monitoring

PREAMBLE INTRODUCTION

Affirming the right of every human being to be adequately nourished, to attain and maintain [as a means of attaining and maintaining] health;

Acknowledging that malnutrition is part of the wider problems [including] poverty, social injustice, lack of education;

Recognizing that the health of humans cannot be isolated from the health of ecosystems;

Conscious that food is indispensible for [an unequalled way of] providing ideal nutrition throughout life [for all ages and life cycles/stages];

Recognizing that the conservation and sustainable use of food biodiversity is an important part of human and (ecosystem) well-being;
Conservation should support the right to food [sustainable diet] and vice versa. Conservation should recognize the right for local populations to benefit from their traditional resources;

Recognizing that when ecosystems are able to support sustainable diets, nutrition programmes, policies and interventions supporting the use of supplements, RUTF, fortificants, and infant formulas are inappropriate and can lead to malnutrition, and that the marketing of these food substitutes and related products can contribute to major public health problems;

[Considering that when] (In periods when) ecosystems are not able to support sustainable diets, there is a legitimate use of supplements, RUTF (ready-to-use therapeutic foods) and fortificants; that all these products should accordingly be made accessible to those who need them through commercial or non-commercial distribution systems; and that they should not be marketed or distributed in ways that may interfere with sustainable diets;

Appreciating that there are a number of social and economic factors affecting sustainable diets; [and that, accordingly] governments should develop [social] support systems to protect, facilitate and encourage them. [and that] governments should create an environment that fosters sustainable diets, provides appropriate family and community support and protection from factors that inhibit it;

Affirming that healthcare systems, and the health professionals and other health workers serving in them, have an essential role to play in guiding sustainable diet practices, encouraging and facilitating sustainable diets, and providing objective and consistent advice to families, communities and governments about the superior value of sustainable diets;

Affirming further that educational systems and other social services should be involved in the protection and promotion of sustainable diets;

Aware that families, communities, women's organizations and other non-governmental organizations have a special role to play in the protection and promotion of sustainable diets, particularly for pregnant and lactating women and infants and young children;

Affirming the need for governments, organizations of the United Nations system, non-governmental organizations, experts in various related disciplines, consumer groups and industry to cooperate in activities aimed at the improvement of human and environmental health through sustainable diets;

Considering that manufacturers and distributors of food substitutes have an important and constructive role to play in relation to sustainable diets, and in the promotion of the aim of this Code and its proper implementation;

Affirming that governments are called upon to take action appropriate to their social and legislative framework and their overall development objectives to give effect to the principles and aim of this Code, including the enactment of legislation, regulations or other suitable measures;

Believing that, in the light of the foregoing considerations, and in view of the vulnerability of ecosystems, and the human health risks involved in inappropriate feeding practices, including the unnecessary and improper use of food substitutes, the marketing of substitutes requires special treatment, which makes usual marketing practices unsuitable for these products.

Annex III

INTERNATIONAL SCIENTIFIC SYMPOSIUM
BIODIVERSITY AND SUSTAINABLE DIETS UNITED AGAINST HUNGER

PROGRAMME

WEDNESDAY, 3 NOVEMBER

08.30-9.30 **Registration**
Sign the Petition 1billionhungry.org

9.30-10.00 **SESSION 1**

OPENING SESSION
Welcoming and Opening Addresses

Changchui He, Deputy Director-General, FAO
Emile Frison, Director-General, Bioversity International

10.00-10.30 **KEYNOTE SPEECH**
Sustainable diets and biodiversity: the challenge for policy, evidence and behaviour change
Timothy Lang, Centre for Food Policy, City University, London

10.30-11.30 **MAINSTREAMING NUTRITION AND BIODIVERSITY FOR SUSTAINABLE DEVELOPMENT**
Chair: Ezzeddine Boutrif, Director
Nutrition and Consumer Protection Division, FAO

Biodiversity and sustainable diets for improved livelihoods for all
Kwesi Atta-Krah, Chairperson,
Alliance Against Hunger and Malnutrition

Global biodiversity outlook 3
Kalemani Jo Mulongoy, Principal Officer, Scientific, Technical and Technological Matters Convention on Biological Diversity-CBD

The cross-cutting initiative on biodiversity for food and nutrition: the common path
Barbara Burlingame, Senior Officer,
Nutrition and Consumer Protection Division, FAO

Opportunities and challenges for nutrition societies to redress malnutrition through food-based approaches
Rekia Belahsen, General Secretary, International Union of Nutritional Sciences

Contribution of agricultural heritage to food and livelihood security
Parviz Koohafkan, Director, Natural Resources Management and Environment Division, FAO

11.30-13.00 **SESSION 2**

FEEDING THE PLANET: THE CHALLENGE OF SUSTAINABLE FOOD PRODUCTION AND CONSUMPTION
Chair: Ezzeddine Boutrif, Director, Nutrition and Consumer Protection Division, FAO

Expo 2015 Milan: feeding the planet-energy for life
Alberto Mina, Director, Institutional Relations EXPO 2015, Milan

Sustainable crop production intensification around the world
William Murray, Senior Officer, Plant Production and Protection Division, FAO

The Dualine project: food sustainability - towards new issues
Louis Georges Soler, Research Director, INRA, France

Animal genetic diversity and sustainable diets - desire versus reality
Roswitha Baumung, Animal Production and Health Division, FAO

Sustainability and diversity along the food chain
Daniele Rossi, Director General, Federalimentare, Italy

Economic implications of sustainable diets
Gianluca Brunori, Agronomy and Agro-Ecosystem Management Department, University of Pisa

13.00-14.30 LUNCH BREAK

14.30-16.00 **SESSION 3**

SUSTAINABLE FOOD CONSUMPTION
Chair: Florence Egal, Senior Officer, Nutrition and Consumer Protection Division, FAO

Ensuring agriculture biodiversity and nutrition remain central to addressing the MDG One hunger target
Jessica Fanzo, Senior Officer, Bioversity International, Rome

Cities as drivers of sustainable food systems
Julien Custot, Facilitator, Food for the Cities Initiative, FAO

Food typologies, food behaviour determinants and actions aiming at improving behaviours for better health
Patrick Etievant, Head, Nutrition, Chemical Food Safety and Consumer Behaviour Division, INRA, France

The contribution of forest biodiversity to sustainable diets
Paul Vantomme, Senior Officer, Forest Economics, Policy and Products Division, FAO

Fish Biodiversity for Sustainable Diets
Helga Josupeit, Officer, Fisheries and Aquaculture Policy and Economics Division, FAO

16.00-16.15 **REPORT ON TECHNICAL WORKSHOP "BIODIVERSITY IN SUSTAINABLE DIETS"**
Sandro Dernini, Consultant, Nutrition and Consumer Protection Division, FAO

16.30-18.00 *ETHIOPIA ROOM/PHILIPPINES ROOM*
Working groups on recommendations

THURSDAY, 4 NOVEMBER

9.00-12.00 **SESSION 4**

BRINGING BIODIVERSITY TO THE PLATE: CASE STUDIES AND PRACTICES PROMOTING FOOD BIODIVERSITY
Chair: Harriet V. Kuhnlein, Founding Director, Professor of Human Nutrition, CINE, Canada

Nutrient diversity within species in major food crops consumed in India
Thing-Nga-Ning Longvah, Deputy Director & Head, Food Chemistry Division, National Institute of Nutrition, Hyderabad, India

Nigerian traditional food system and nutrition security
Ignatius Onimawo, President, Nutrition Society of Nigeria, Nigeria

***Canarium odontophyllum* Miq.: an underutilized fruit for human nutrition and sustainable diets**
Ismail Amin, Department of Nutrition and Dietetics,
Faculty of Medicine and Health Sciences University Putra,
Selangor, Malaysia

Assessing nutritional diversity of cropping systems in African villages
Roseline Remans, Tropical Agriculture and Rural Environment Programme, The Earth Institute, Columbia University, New York

Edible insects in Eastern and Southern Africa: challenges and opportunities
Muniirah Mbabazi, Department of Food Science and Technology Makerere University, Kampala, Uganda

Comparing study of antioxidant activities of sea buckthorn /Hippophae rhamnoides/, cowberry /*Vaccinium vitis-idaea*/, and carrots species, adopted in Mongolia
Enkhtaivan Gombosuren, Head, Department of Nutrition and Food Services, Mongolian University of Science and Technology, Mongolia

Fruit trees in home gardens of the Nuba mountains, Central Sudan, and their contribution to household nutrition and income
Katja Kehlenbeck, World Agroforestry Centre ICRAF, Kenya

Conservation of plant biodiversity for sustainable diets
Kate Gold, International Projects Coordinator, Millennium Seed Bank Partnership, Seed Conservation Department, Royal Botanic Gardens, United Kingdom

12.00-13.00 *ETHIOPIA ROOM/PHILIPPINES ROOM*
Working groups on recommendations

13.00-14.30 LUNCH BREAK

14.30-16.00 **SESSION 5**

BIODIVERSITY AND NUTRITION, A FOOD-BASED APPROACH
Chair: Rekia Belahsen, General Secretary, International Union of Nutritional Sciences

Opening remarks
Denis Lairon, President, European Federation of Nutrition Societies

Food, nutrition security and biodiversity in West African countries: Opportunities and challenges
Ismael Thiam, West African Health Organization, Burkina Faso

Revisiting the vitamin A fiasco: going local in Micronesia
Lois Englberger, Island Food Community of Pohnpei, Federated States of Micronesia

The challenges of overcoming rural poverty and malnutrition through local foods in West Africa
Amadou Tidian Guiro, Department of Animal Biology, University of Cheikh Anta Diop, Dakar, Senegal

Bioactive components in indigenous African vegetables
Francis Omujal, Natural Chemotherapeutics Research Laboratory, Ministry of Health, Uganda

Aquaculture with small fish species has the potential to improve nutrition and combat micronutrient deficiencies
Shakuntala Thilsted, The World Fish Center, Bangladesh

Nutrition indicators for biodiversity
Ruth Charrondière, Nutrition and Consumer Protection Division, FAO

16.00-17.30 **SESSION 6**

BIODIVERSITY, FOOD COMPOSITION AND SUSTAINABLE DIETS
Chair: Barbara Burlingame, Senior Officer, Nutrition and Consumer Protection Division, FAO

AFROFOODS call for action from the door of return
Isaac Akinyele, Elected Coordinator, AFROFOODS, Nigeria

Recent achievements in Europe through EuroFIR and BaSeFood projects
Paul Finglas, Coordinator, EuroFIR & EUROFOODS, United Kingdom

Research projects and activities on biodiversity, food composition and sustainable diets among SAARCFOODS members
Thing-Nga-Ning Longvah, Elected Coordinator, SAARCFOODS, India

Research projects and activities on biodiversity, food composition and sustainable diets among ASEANFOODS members
Prapasri Puwastien, Coordinator, ASEANFOODS, Thailand

Achievements on biodiversity in relation to food composition in Latin America
Lilia Masson, Professor Emeritus, University of Chile, Chile

17.30-18.30 *ETHIOPIA ROOM/PHILIPPINES ROOM*
Working groups on recommendations

FRIDAY, 5 NOVEMBER

9.00-11.30 **SESSION 7**

THE MEDITERRANEAN DIET AS AN EXAMPLE OF A SUSTAINABLE DIET
Coordinated by the National Institute of Food and Nutrition Research (INRAN), Italy.
Chair: Carlo Cannella, Director, International Interuniversity Studies Center on Mediterranean Food Cultures (CIISCAM), Italy

Keynote Address
Pietro Sebastiani, Permanent Representative of the Republic of Italy to FAO

The Mediterranean diet as intangible world heritage
Pier Luigi Petrillo, Director, Task Force UNESCO, Cabinet of the Minister of Agriculture, Food and Forestry Policies (MiPAAF), Italy

The Mediterranean diet at the beginning of the 3rd millennium
Cosimo Lacirignola, Director, CIHEAM-IAMB, Italy

MiPAAF Biovita project: Biodiversity and Mediterranean diet
Giuseppe Maiani, Program Director, INRAN, Italy

MiPAAF Bioqualia project: Organic farming, sustainability and biodiversity
Flavio Paoletti, Programme Director, INRAN, Italy

Mediterranean diet: an integrated view
Mauro Gamboni, Head, Technical Scientific Planning Unit, Agro-Food Department, CNR, Italy

Is the Mediterranean diet, world paragon, sustainable from field to plate?
Martine Padilla, Scientific Director, CIHEAM-IAMM, France

Food and energy: a sustainable approach
Massimo Iannetta, Head, Sustainable Development and Innovation of Agro-industrial System Unit, ENEA, Italy

Double Pyramid: Healthy food for people, sustainable food for the planet
Andrea Poli, Barilla Center for Food and Nutrition, Italy

11.30-12.30 **A PLATFORM FOR ACTION ON BIODIVERSITY AND SUSTAINABLE DIETS**
MAIN RECOMMENDATIONS
Chair: Barbara Burlingame, Senior Officer, Nutrition and Consumer Protection Division, FAO

12.30-13.00 **CLOSING REMARKS**

Ezzeddine Boutrif, Director, Nutrition and Consumer Protection Division, FAO
Emile Frison, Director-General, Bioversity International

Annex IV

INTERNATIONAL SCIENTIFIC SYMPOSIUM
BIODIVERSITY AND SUSTAINABLE DIETS UNITED AGAINST HUNGER

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INTERNATIONAL SCIENTIFIC SYMPOSIUM
BIODIVERSITY AND SUSTAINABLE DIETS UNITED AGAINST HUNGER

LIST OF BACKGROUND PAPERS

1) Framework for a Cross-cutting Initiative on Biodiversity for Food and Nutrition, Decision VIII/23A, 8th Conference of the Parties of the Convention on Biological Diversity, Curitiba, Brazil, 2006; http://www.cbd.int/decision/cop/?id=11037

2) Toledo, A. and Burlingame, B., Biodiversity and nutrition: A common path toward global food security and sustainable development. Journal of Food Composition and Analysis. 19 (2006) 477-483

3) John, T. and Eyzaguirre, P., Linking biodiversity, diet and health in policy and practice. Proceeding of the Nutrition Society. 65 (2006) 182-189

4) Herrin, M. and Gussow, JD., Designing a Sustainable Regional Diet, Journal Nutrition Education. 21 (1989) 270-275

5) The CIHEAM Watch Letter, The Mediterranean Diet, Spring 2010, N. 13

6) Sustainable Development Commission. Setting the Table, Advice to the Government on priority elements of sustainable diets. 2009

7) Lang, T., What is a sustainable diet for planet earth? paper non published, 2009

8) FAO and SINER-GI. Linking People, Places and Products. A guide for promoting quality linked to geographical origin and sustainable geographical indications. 2009

9) Barilla Center for Food and Nutrition. Double Pyramid: Healthy Food for People, Sustainable Food for the Planet, www.barillacfn.com/uploads/file/72/1277905159_PositionPaper_BarillaCFN_Double-Pyramid.pdf

10) AFROFOODS Call for Action from the Door of Return, Dakar, 10 December 2009, http://www.fao.org/infoods/AFROFOOD%20CALL%20and%20APPEL.pdf

11) CIISCAM. The Mediterranean Diet Today, A Model of Sustainable Diet. Conference Brochure, Parma, Italy, 3 November 2009, http://www.ciiscam.org/files/download/Convegni%20ed%20Eventi/parma_brochure_en.pdf

Annex VI

AFROFOODS CALL FOR ACTION FROM THE DOOR OF RETURN FOR FOOD RENAISSANCE IN AFRICA

House of the Slaves, Goree, Dakar, Senegal
10 December 2009 – Human Rights Day

We, the participants at the Fifth AFROFOODS Sub-regional Data Center Coordinators Meeting held in Dakar, Senegal, on 9–11 December 2009,

- Note that the degradation of ecosystems and the loss of food biodiversity is contributing greatly to the increases in poverty and malnutrition in Africa;
- Recognize that returning to local crops and traditional food systems is a prerequisite for conservation and sustainable use of biodiversity for food and nutrition;
- Acknowledge that local foods are the basis for African sustainable diets;
- Urge that food composition data be emphasized as the fundamental information underpinning almost all activities in the field of nutrition;
- Call upon the sectors of public health, agriculture, and environment and food trade to help reinforce and assist with the improvement of food composition data, particularly on local foods;
- Request that the contribution of food composition be credited as one of the most important components for action in nutrition and food quality, food safety, and food and nutrition security.

We invite all sectors to place AFROFOODS on the national, regional and international agenda for all food and nutrition activities in Africa through interdisciplinary strategic plans for achieving the relevant MDGs; and therefore, from the Door of Return of the House of the Slaves of Gorée-Dakar, we accept the challenge ourselves and send this call for action to our colleagues, as well as to governments, the private sector and financial entities, to strengthen AFROFOODS activities in a renewed commitment to an African food renaissance.

SUSTAINABLE DIETS AND BIODIVERSITY

DIRECTIONS AND SOLUTIONS FOR POLICY, RESEARCH AND ACTION

This book presents the current state of thought on the common path of sustainable diets and biodiversity. The papers contained herein address the linkages among agriculture, health, the environment and food industries.

The alarming pace of biodiversity loss and ecosystem degradation and their negative impact on poverty and health makes a compelling case for re-examining food systems and diets. Thus, there is an urgent need to develop and promote strategies for sustainable diets, emphasizing the positive role of food biodiversity in human nutrition and poverty alleviation.

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Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.

The contents of this book represent the presentations given at the International Scientific Symposium on Biodiversity and Sustainable Diets, organized by FAO and Bioversity International and held at FAO, Rome, from 3 to 5 November 2010.