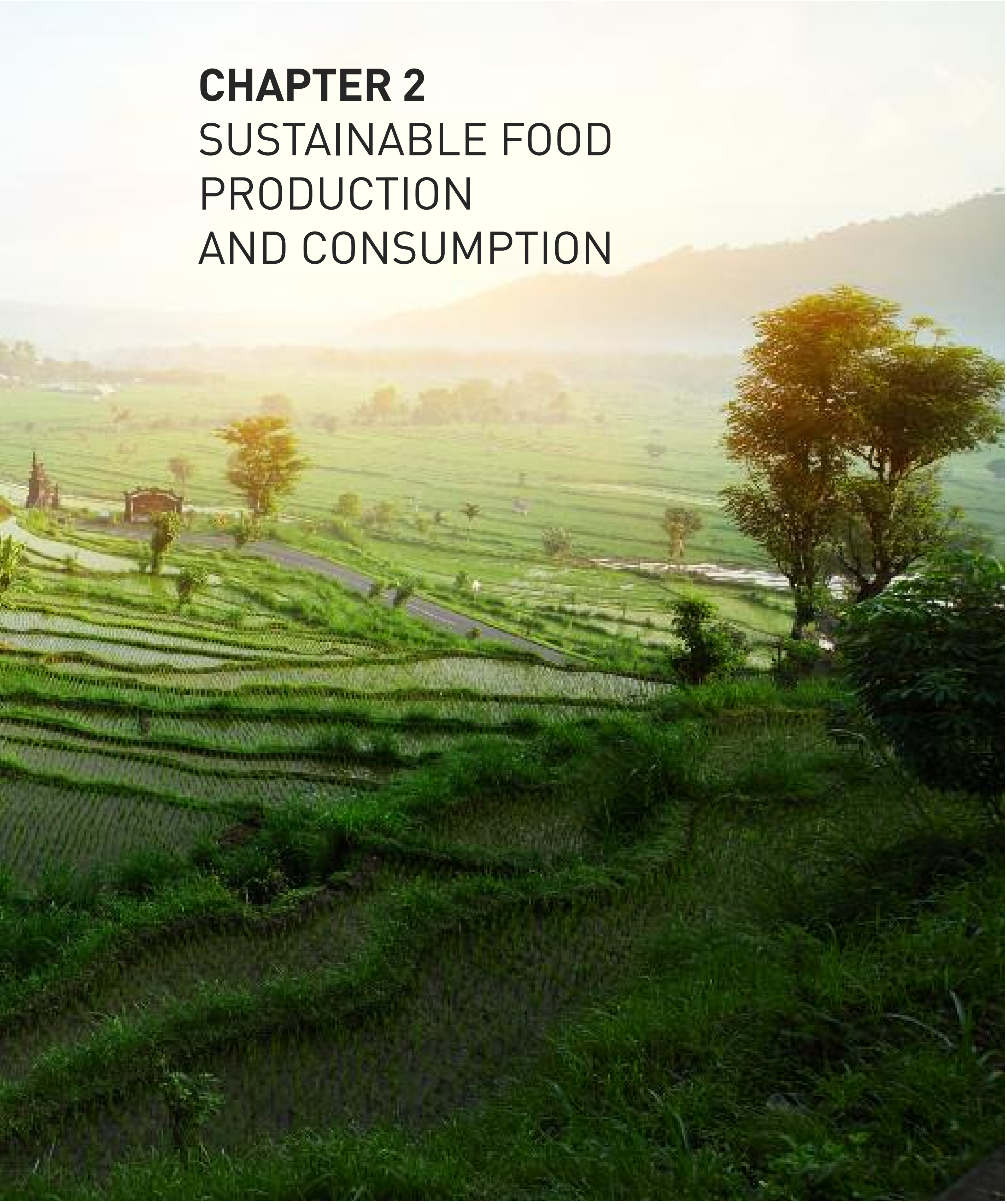
CHAPTER 2
SUSTAINABLE FOOD PRODUCTION AND CONSUMPTION



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

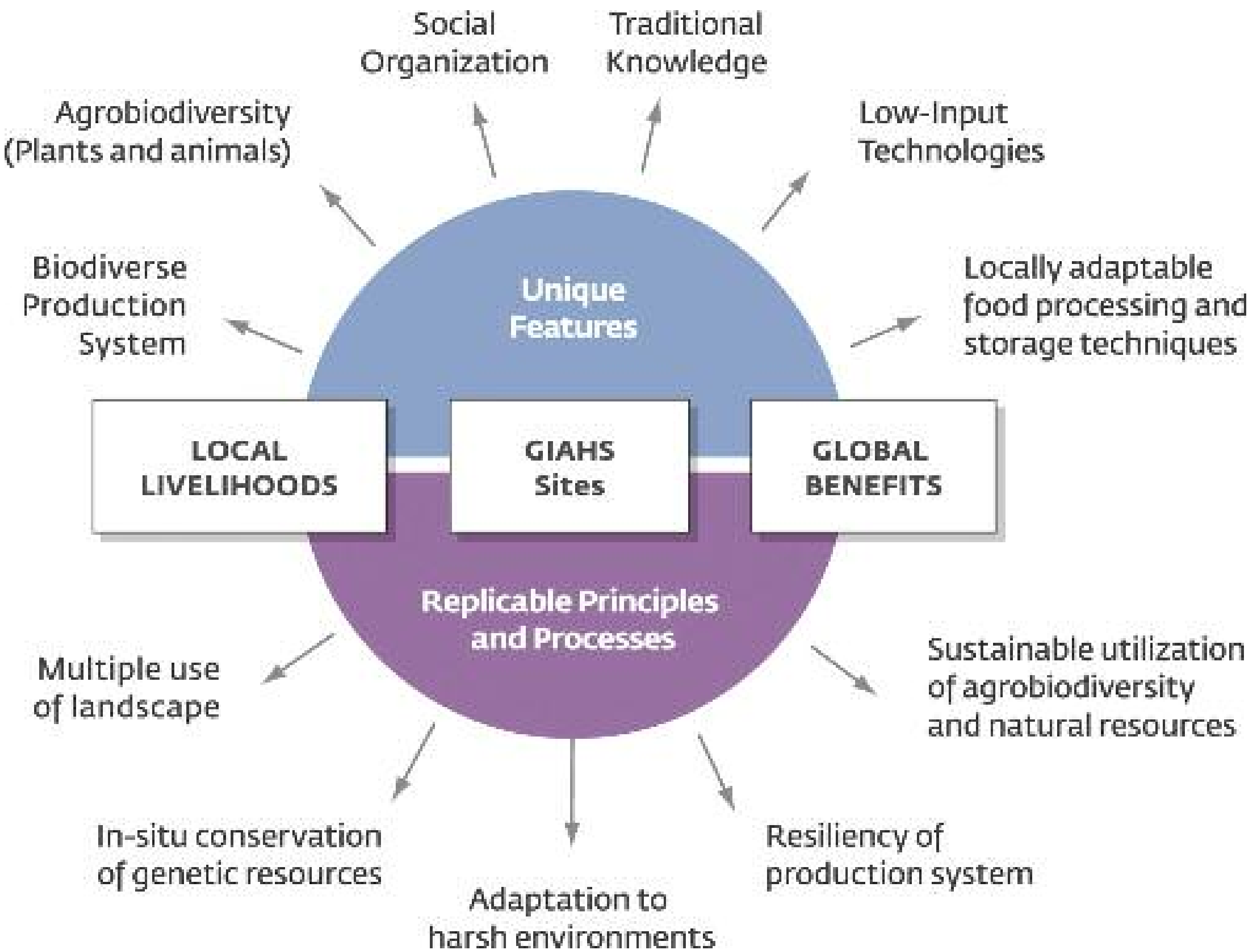

Figure 1. The unique features and principles of GIAHS sites that may be replicated in other farming systems to achieve sustainability and resiliency.

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.

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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).

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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)

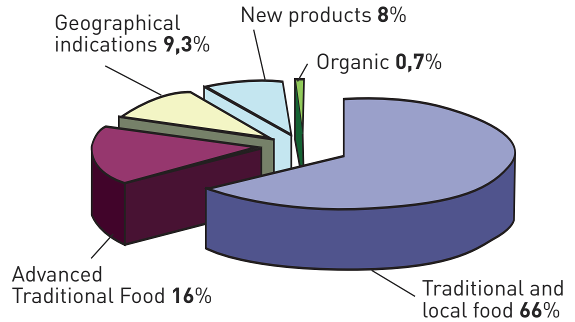

Table 2. Italian food and drink industry: turnover by product. (Data and estimates Federalimentare 2110)

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.

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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).

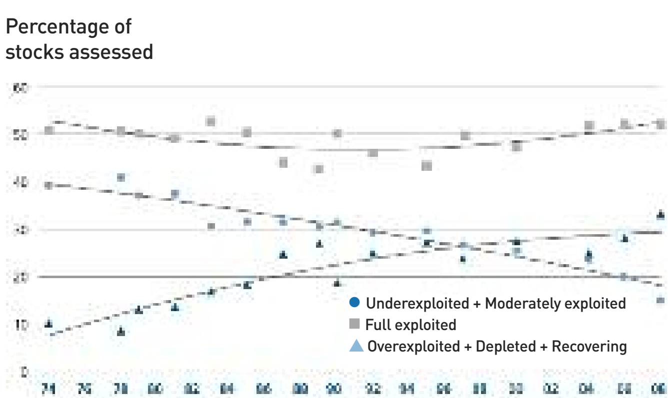

Figure 1. Global trends in the state of world marine stocks since 1974 (FAO, 2011a).

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.

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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.

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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

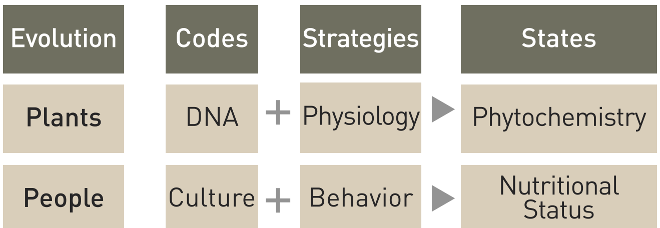

Figure 1. Nutritional adaptation and biocultural evolution.

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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