GREENING THE ECONOMY WITH CLIMATE-SMART AGRICULTURE

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ACRONYMS

CH4	Methane
CGRFA	Commission on Genetic Resources for Food and Agriculture (CGRFA)
CLCPRO	Commission for Controlling the Desert Locust in the Western Region
CSA	Climate-Smart Agriculture
CO_2	Carbon Dioxide
EIT	Economies in Transition
EMBRAPA	Brazilian Agricultural Research Corporation
EMPRES	Emergency Prevention System
FAO	Food and Agriculture Organization of the United Nations
FSCA	Food Security for Commercialisation for Agriculture
GDP	Gross Domestic Product
GFFBO	Good Father Fishery Based Organization
GHG	Greenhouse Gas
HLPE	High Level Panel of Experts on Food Security and Nutrition
IDP	Internally Displaced Persons
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
N_2O	Nitrous Oxide
NAPA	National Adaptation Programmes of Action
NGO	Non-governmental Organization
NLCUs	National Locust Control Units
NPFS	National Program for Food Security
OECD	Organization for Economic Co-operation and Development
ORAM	Rural Association for Mutual Support
REDD	Reducing Emission from Deforestation and Forest Degradation
SBSTA	Subsidiary Body for Scientific and Technological Advice
SCP	Sustainable consumption and production
SCPI	Sustainable crop production intensification
SIDS	Small Island States
UDP	Urea Deep Placement
UNCED	United Nations Conference on Environment and Development
UNCTAD	United Nations Conference on Trade and Development
UN DESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNCSD	United Nations Conference on Sustainable Development
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization

SCOPE OF PAPER

Agriculture has to address simultaneously three intertwined challenges: ensuring food security through increased productivity and income, adapting to climate change and contributing to climate change mitigation. To accomplish this, food systems have to become, at the same time, more efficient and resilient, at every scale from the farm level to the global level. Radical changes are needed in agricultural and food systems. These changes can play an essential role in greening the economy and contributing to sustainable development.

This paper considers the intertwined challenges of food security and climate change, potential impacts of climate change on agriculture, and the impact of agriculture on climate. It further develops and illustrates with concrete examples the concepts of increasing resource efficiency and building resilience as guiding principles to address these challenges. It shows how changing practices in the field can drive sustainable economic development.

KEY MESSAGES:

1. Agriculture and food systems must undergo significant transformations in order to meet the related challenges of food security and climate change.

2. Increasing resource efficiency is essential both to increase and ensure food security on the long term and to contribute to mitigate climate change.

3. Building resilience to every type of risk is essential to get prepared to uncertainty and change.

4. Efficiency and resilience have to be considered together, at every scale and from both environmental, economic and social perspectives.

5. Implementing Climate-Smart Agriculture can be a major driver of Green Economy.

6. Greening Economy with Climate-Smart Agriculture is a concrete way to operationalize sustainable development.

7. Addressing food security and climate change requires concerted and coordinated involvement and action of all stakeholders on a long term perspective.

1. INTRODUCTION

In 1992, five years after the release of the 1987 Brundtland report, the United Nations Conference on Environment and Development (UNCED), also known as the "Earth Summit" was held in Rio de Janeiro. The conference articulated the notion of sustainable development and launched milestone international agreements on environment, the "Rio conventions", including the United Nations Framework Convention on Climate Change (UNFCCC).

Twenty years after, the United Nations Conference on Sustainable Development, commonly called Rio+20 or the Rio Earth Summit 2012, was also held in Rio. While some progress has been made towards sustainable development between 1992 and 2012, challenges remain huge as human footprint on the planet is increasing and some 'planetary boundaries' are (or are close to be) exceeded. We are now at a time when it is urgent to give a new and more concrete expression to the classical theoretical apparatus of sustainable development, make it more operational, and pave ways on how to integrate its three dimensions. This is also why the concept of the 'green economy' was developed.

Agriculture, (intended in the FAO sense of 'agriculture, forestry and fisheries') is at the nexus of the challenges that need to be addressed to make sustainable development a reality (FAO, 2012a).

One of the first planetary boundaries, perhaps the most important one, is that the world needs to feed itself. But, today, almost one billion people are hungry. Another billion is malnourished, lacking essential micronutrients. While, globally, enough food is being produced to feed the entire word, one-third of it is lost or wasted, and stable economical and physical accessibility to food is still a problem for one out of six people on our planet. By 2050, food production has to increase, both in quantity, quality, and diversity, especially in developing countries. Population and income growth will drive up an ever increasing demand, especially in developing countries (Lutz and Samir, 2010; Cirera and Masset, 2010; Foresight, 2011a; Foresight, 2011b). Assuming these trends continue, FAO estimates that production has to increase by 60 percent between now and 2050, especially in developing countries (Bruinsma, 2009; Conforti, 2011). Food systems have to satisfy this growing demand, both in quantity, quality and diversity.

Agriculture is also an essential driver of economic growth, particularly in rural areas and least developed countries. At the national level boosting agricultural production stimulates overall economic growth and development, particularly in those countries with a high economic dependence on agriculture. According to World Bank (2008) investment in agriculture is particularly efficient in creating new jobs. Agricultural and rural development acts as an engine for sustainable economic development, making an effective contribution to national economic growth. At the community level, agricultural development increases farm productivity, reduces food deficits, increases food surpluses and raises incomes. Improved agriculture production provides opportunities to sustainably reduce poverty, food insecurity and malnutrition and thereby improves livelihoods.

At the same time, food production and consumption already exerts a considerable impact on the environment (UNEP, 2010; FAO, 2012b). Food systems rely on resources, especially land, water, biodiversity, and fossil fuels, which are becoming ever more fragile and scarce.

Agriculture is an important source of greenhouse gases (GHGs). It is responsible for 70 percent of water withdrawal. It is an important driver of deforestation and loss of biodiversity. Fisheries, which provide unique sources of protein and fatty acids, are fully dependent on healthy ecosystems, but unsustainable practices often result in major negative impacts on the aquatic environment and its resources. The global food system is currently very dependent on fossil fuels (Brodt, 2007; Woods *et al.*, 2010; FAO, 2011c) that contribute to GHG emissions and may increase input costs to the extent that they become unaffordable for increasing production.

As stated in the outcome document of the Rio+20 conference the "green economy in the context of sustainable development and poverty eradication will enhance our ability to manage natural resources sustainably and with lower negative environmental impacts, increase resource efficiency and reduce waste."[1] Agriculture is essential for a green economy. In fact, FAO considers that there can be no green economy without agriculture. This is why FAO proposed "Greening Economy with Agriculture" as the key message for Rio+20 (FAO, 2012b).

Climate-smart agriculture (CSA), as defined and presented by FAO (FAO, 2010a) at the Hague Conference on Agriculture, Food Security and Climate Change, contributes to the goals of making sustainable development concrete. It integrates the three dimensions of sustainable development in addressing food security and climate concerns in a forward looking perspective.

As mentioned earlier, agriculture has to address simultaneously three intertwined challenges: ensuring food security through increased productivity and income, adapting to climate change and contributing to climate change mitigation (FAO, 2010a; Foresight, 2011a; Beddington *et al*., 2012a; Beddington et al., 2012b; HLPE, 2012a). Addressing these challenges will require radical changes in our food systems. It is precisely to articulate these changes that FAO has forged the concept of CSA as a way forward for food security in a changing climate. CSA aims to improve food security, help communities adapt to climate change and contribute to climate change mitigation by adopting appropriate practices, develop enabling policies and institutions and mobilizing needed finances.

To address these three intertwined challenges, food systems have to become, at the same time, more efficient and resilient, at every scale from the farm level to the global level. They have to become more efficient in resource use (use less land, water, inputs to produce more food sustainably) and become more resilient to changes and shocks. These principles are also central in the Rio + 20 outcome document[2], which recognizes resource efficiency as key to a green economy and affirms the need to enhance agriculture's resilience.

The transformation towards CSA is in complete accordance with "Greening Economy with Agriculture" because it works to produce more with less resources and creates new opportunities, new jobs, new enterprises that both serve to enable this transformation and as a result of it.

1 "The future we want" accessible at http://www.uncsd2012.org/thefuturewewant.html paragraph 60.

2 Id paragraphs 108-118.

2. FOOD SECURITY AND CLIMATE CHANGE: THREE INTERTWINED CHALLENGES[3]

Agriculture and food systems have to, and will have to, improve and ensure food security, and to do so to adapt to climate change, and contribute to mitigating climate change. These challenges, being interconnected, have to be addressed simultaneously.

2.1. Ensuring food security

The world is producing enough food, but there are still 925 million people estimated to be undernourished in 2010, representing almost 16 percent of the population of developing countries (FAO, 2010b). In addition, another billion people are malnourished, lacking essential micronutrients. The paradox is that 60 percent of the malnourished actually are food producers, smallholders and pastoralists, with 20 percent living in cities and 20 percent landless rural people. For the poor producers, food is not only a basic need, it is the single, and often fragile, support they have for maintaining their livelihood. What is true at the household level is also true at the macroeconomic level. There are 32 countries, 20 of them in Africa, facing food crises and in need of international emergency action. In most of these countries, paradoxically, agriculture is an important, if not the major, part of economy.

The objective is to ensure food and nutrition security, worldwide. It is not only availability of calories and sufficient global production that has to be ensured. We also need to make sure that enough food is accessible to everyone, everywhere, physically and economically. In addition, we need to ensure that this food is properly utilized in the right quality and diversity. The goal is to ensure the stability of these three components of food and nutrition security: availability, access and utilization.

Between now to 2050, the world's population will increase by one-third. The additional 2 billion people will live in developing countries. At the same time, more people will be living in cities (70 percent against the current 50 percent). Urbanization and rising incomes in developing countries are driving increases in the consumption of animal products (FAO, 2009a). Given these trends, FAO estimates that business as usual production will have to increase by 60 percent by 2050 to satisfy the expected demands for food and feed (Conforti, 2011). Demand for biofuels, another important factor for global food security, is very dependent on national policies and it is expected to grow. According to the OECD-FAO projections, because of increasing mandates and consumption incentives, biofuel production is expected to double between 2005 and 2019 (OECD-FAO, 2010).

2.2. Impacts of climate change on agriculture

Climate change is suspected of having already significantly impacted agriculture (Lobell et al, 2011) and is expected to further impact directly and indirectly food production. Increase of mean temperature; changes in rain patterns; increased variability both in temperature and rain patterns; changes in water availability; the frequency and intensity of 'extreme events'; sea level rise and

3 This section draws heavily on Meybeck A. Gitz V. Towards Efficiency & Resilience in Agriculture for Food Security in a Changing Climate presented at the OECD-KREI Expert Meeting on Green Growth and Agriculture and Food in Seoul, Korea 6-8 April 2011

salinization; perturbations in ecosystems, all will have profound impacts on agriculture, forestry and fisheries (Gornall, 2010; IPCC, 2007a; Beddington *et al.*, 2012b; HLPE, 2012a; Thornton *et al.*, 2012). The extent of these impacts will depend not only on the intensity of the changes but also on their combination, which are more uncertain, and on local conditions. Anticipating appropriately the impacts of climate change on agriculture requires data, tools and models at the spatial scale of actual production areas. Since the last Intergovernmental Panel on Climate Change (IPCC) report in 2007 some studies have attempted to anticipate these impacts and provide projections at such a scale, enabling us to have a more concrete vision of projected changes.

A prospective study in Morocco (World Bank, 2009a) points to gradually increasing aridity due to reduced rainfall and higher temperatures, with negative effects on agricultural yields, especially from 2030 onwards. Rainfed crops are expected to be particularly affected. If irrigation water continues to be available in sufficient quantities, irrigated crop yields might continue to increase in spite of climate change. However, this will depend on the availability of water for irrigation. In this study, if agricultural yields will remain more or less stable up to 2030, they are predicted to drop rather quickly beyond this date.

A study in Brazil (EMBRAPA, 2008) shows that climate change can have dramatic changes in the potentials for the various crops analysed and their potential geographic repartition. Globally, the increase of evapotranspiration leads to an increase of the areas at high climatic risk for 7 of the 9 crops analysed (cotton, rice, coffee, beans, sunflower, millet, soya bean) and a decrease for cassava and sugar cane. It will also cause important displacements in areas suitable for crops, especially for coffee and cassava. In traditional production areas, coffee would be affected by lack of water or high temperatures. In the States of São Paulo and Minais Gerais coffee would no longer be cultivated in areas where it is currently cultivated. On the other hand, with the reduction of the risk of frost, there could be an increase of the production area in Paraná, Santa Catarina and Rio Grande do Sul. As a result, the global area at low climatic risk for coffee would be reduced by 9.5 percent in 2020, 17 percent in 2050, and 33 percent in 2070. On the other hand, favourable areas for sugar cane will considerably increase.

The impacts of climate change will have major effects on agricultural production, with a decrease of production in certain areas and increased variability of production to the extent that important changes may need to be made in the geographic area where crops are cultivated. Local impacts will bring global imbalances. Broadly speaking, with everything else being equal, climate change may lead to an increase in both crop and livestock productivity in mid to high latitudes (IPCC, 2007a) and a decrease in tropical and subtropical areas. Among the most affected areas are economically vulnerable countries already food insecure and some important food exporting countries. This will induce profound changes in trade, with impact on prices and on the situation of net food importing countries. Consequently, climate change is expected to increase the gap between developed and developing countries as a result of the more severe impacts in already vulnerable developing regions, exacerbated by their relatively lower technical and economical capacity to respond to new threats (Padgham 2009). Smallholders and pastoralists will suffer complex, localized impacts (IPCC 2007a). According to the International Food Policy Research Institute (IFPRI) (Nelson *et al.*, 2010), it will cause an increase of between 8.5 and 10.3 percent in the number of malnourished children in all developing countries, relative to scenarios of perfect climate change mitigation.

The models used for such projections do not take into account the impacts of multiple stress induced by climate change, nor the impacts on the functioning of ecosystems, such as effects on pollinators (FAO 2011a) and the balance between pests and their predators, nor impacts on animal diseases (FAO-OECD, 2012; HLPE, 2012a).

There will also be probably important effects on nutrition as a result of climate change. To date, studies mostly focus on cereals. There is a need to better capture all the nutritional consequences of the effects of climate change on other foods and vegetables and wild foods, all of which have an important role in balanced diets and which are at risk (HLPE, 2012a; Barucha and Pretty, 2010).

In terms of impacts, it is necessary to distinguish between increased variability and slow onset changes. The potential impacts of increased variability are often less emphasized than slow onset changes for a variety of reasons. This is because these impacts are less well known (HLPE 2012a) even though they will be felt first. The impacts of increased variability are situated between the much emphasized category of 'extreme events'", and the much more 'easier to grasp' business as usual category of actual variability. And what exactly is an "extreme event"? What makes an event considered as "extreme"? Is it the intensity, the infrequency of a meteorological event? Or is it the extent and intensity of its consequences? For agriculture it can be very different. A slight change in temperature at a critical stage of plant growing can compromise a crop. As changes in variability are easier to grasp by farmers now, they make an easier target for early adaptation measures (Padgham, 2009). It is therefore important to distinguish between these two categories of impacts to distinguish two ways to adapt, each with different time ranges: increasing resilience now to get prepared for more variability, and increasing adaptive capacities and preparedness for slow onset changes. Furthermore, getting prepared for more variability is also a way to get prepared for any change, whatever it may be.

2.3. Agriculture's impact on climate change

The agriculture sector has to produce more food and it will be certainly impacted by climate change. It has also been called upon to contribute to mitigate climate change (UNFCCC, 2008). The question is how and to what extent agriculture and food systems can contribute to climate change mitigation without compromising food and nutrition security.

In 2005, agriculture (crop and livestock) accounted for 13.5 percent of global GHG emissions (IPCC, 2007b). This figure is based on activities carried out in the fields and with livestock. But agriculture's role in the climate change, and, importantly, its mitigation potential, should be considered in a wider perspective of 'food systems'. This includes the impact these systems have on forests, the energy sector and transport. Expanding our consideration of agriculture's role in climate change is warranted because some of the on farm emissions are not included in 13.5 percent figure, but are grouped in other sectors, such as electricity used in farm buildings and fuel used in farm equipment and food transport. Also, agriculture is a major driver of deforestation, which roughly accounts for an additional 17 percent of global GHG emissions (IPCC, 2007b). This is why agriculture is included in the study on the drivers of deforestation, which was requested by the UNFCCC's 17th Conference of the Parties (COP 17) in Cancun to the Subsidiary Body for Scientific and Technological Advice (SBSTA). Finally, within food systems, reductions of emissions in some areas could lead to increases elsewhere. For instance, depending on production systems, shorter food chains could reduce transport but increase agricultural emissions. Currently, there are no studies that quantify emissions from the global food system (Garnett, 2011). A study in 2006 estimated that 31 percent of the European Union's GHG emissions were associated with the food system (European Commission, 2006). So, when looking at challenges and opportunities to reduce GHG emissions using agriculture, it is paramount to look beyond the farm, vertically into the whole food chain and horizontally across impacted land-uses such as forests.

The main direct sources of GHG emissions in the agricultural sector are not carbon dioxide (CO_2). Agriculture is a source of nitrous oxide (N_2O), accounting for 58 percent of total emissions, mostly by soils and through the application of fertilizers, and of methane (CH_4), accounting for 47 percent of total emissions, essentially from livestock and rice cultivation. These emissions are dependent on natural processes and agricultural practices, which makes them more difficult to control and measure. On the other hand agriculture is a key sector in that, with forestry, management can lead to biological carbon capture and storage in biomass and soil, acting as "sinks".

As agricultural production is projected to increase in developing countries, so are agricultural emissions. IPCC (2007b) estimates that N_2O emissions will increase by 35 - 60 percent by 2030 and CH_4 by 60 percent. The IPCC also projects additional land being converted to agriculture.

There are two ways to mitigate climate change while keeping with the 'food security first' objective. The first way is to decorrelate (or decouple) production growth from emissions growth. This involves reducing emissions per kilogram of food output (included in this calculation are the effects of emissions from reduced deforestation per kilogram of food). The second way is to enhance soil carbon sinks. The IPCC (2007b) estimates the global technical mitigation potential from agriculture to be the equivalent of 5 500-6 000 tonnes of CO_2 per year by 2030. This is grossly equivalent to three quarters of the sector's emissions in 2030 (around 8 200 tonnes of CO_2). About 70 percent of this identified potential lies in developing countries , 20 percent in OECD countries, and 10 percent for EIT countries. IPCC estimates that nine-tenths of the global mitigation potential of agriculture is linked, not to reduction of agricultural GHG (mainly CH_4 and N_2O) emissions, but to managing land carbon stocks. This involves enhanced soil carbon sequestration, reduced tillage, improved grazing management, the restoration of organic soils and restoration of degraded lands.

Reducing emissions per kilogram of output might well be, for food security and agriculture, one of the main targets. Direct gains through increased efficiency also imply a series of indirect gains. These indirect gains include reduced emissions from deforestation (not accounted in IPCC's calculations of the 90 percent) as less land is necessary to produce the same amount of food. Indirect gains also include reduced emissions from the production of fertilizer or energy inputs used on the farm. Everything else being equal, a potential reduction equivalent to 770 tonnes of CO_2 per year by 2030 has been identified from reduction of fossil fuel use through improved on-farm energy efficiency. In addition, there are potential reductions through improved efficiency in food chains, including a reduction of post-harvest losses.

3. TOWARDS MORE EFFICIENT AND RESILIENT SYSTEMS

To address these three intertwined challenges, food systems have to become at the same time more efficient and resilient, at every scale from the farm to the global food system. They have to become more efficient in resource use; use less land, water and inputs to produce more food sustainably, and more resilient to changes and shocks.

3.1 More efficient systems

3.1.1. Increase resource efficiency

Increasing efficiency in the use of resources (i.e. producing more of a given output using less of a given input) is at the core of the concept of a green economy.

The green economy is driven by the idea that, in the long run, given the increasing scarcity of resources, physical resource efficiency and economic efficiency will get closer, including through policies which would factor in environmental and social externalities (positive and negative) of input use and production. Agriculture needs to produce more with resources (land, water, energy and nutrients) that are becoming scarcer and more expensive. However, given the relative prices of the various inputs, production factors and outputs, this is not yet always the case now. Evidence shows that farmers economize in their use of inputs in reaction to increased prices (OECD 2011). A study of how US farmers reacted to higher energy and fertilizer prices in 2006 (Harris et al, 2008) showed that 23 percent of commercial farms reduced their usage of both energy and fertilizers. To reduce energy consumption, they used machines less intensively and serviced engines more frequently. Lower usage of fertilizers was achieved through greater use of soil testing, precision application and changes of crops.

Increasing efficiency in the use of resources is also one of the driving principles of CSA. GHG emissions from agriculture are linked to its use of resources. Three production factors have an important influence on total agricultural GHG emissions: (i) area, because bringing more surface under cultivation would require either deforestation or grasslands being converted to croplands, which would induce CO_2 emissions, and (ii) fertilizers, whose production is an important source of CO_2 and which at the field level translate in nitrous oxide emissions, (iii) livestock, which is an important source of methane and nitrous oxide emissions. Machines are also a factor, both directly by energy use and indirectly by their production. Everything else being equal, increasing the efficiency in the use of one of these production factors decreases emissions intensity of the output. As irrigation often demands considerable energy, water efficiency is another key factor for increasing production, adapting to climate change and reducing emissions.

Resource efficiency should be improved in every type of food system. Studies using the results of detailed on farm energy audits realized in France have shown that energy consumption per kilogam of output can be extremely variable between farms. It has for instance been shown (Bochu et al, 2010) that the most efficient dairy farms consume half of the energy consumed by the less efficient farms. Results of more than 400 farms have been analysed and categorized according to the importance of corn silage in the system (1-10 percent, 10-20 percent, 20-30 percent, more than 30 percent of the feed). It appears that variability among each of these categories is more important than between categories, and that in every category the more efficient farms use less than half of the energy used by the less efficient ones. This is also true in organic farms. This means that, no matter what the system, there can be important improvements in management practices.

3.1.2 Increase resource efficiency in plant production

As agriculture is an important driver of deforestation, reducing agricultural expansion through sustainable intensification on already cultivated land could have a major mitigation effect. The HLPE (2012a) considers that ending most conversion of forest to cultivation should be a mitigation priority.

Burney et al. (2010) shows that, at the global level, from 1961 to 2005, crop production increased by over 160 percent, mostly as a result of 135 percent yield increases, with only 27 percent increases in crop area. This intensification allowed farmers to feed the world while emitting the equivalent of 590 gigatonnes of CO_2 less than would have been emitted by expanding the area under cultivation under 1961 yields. They conclude that land use change emissions (even avoided ones) are much more important than direct emissions from agricultural systems. Therefore, improvement of crop yields should be prominent in any mitigation strategy. Moreover, these improvements will also contribute to preserving forest sinks and maintaining their capacity to store carbon over the long-term future (Gitz and Ciais, 2004).

Gibbs et al. (2010) find that across the tropics, between 1980 and 2000, more than 55 percent of new agricultural land came at the expense of intact forests and another 28 percent came from disturbed forests. Considering the role of agriculture as a driver of deforestation, sustainable intensification should also play a part in Reducing Emissions from Deforestation and Forest Degradation (REDD) programmes. Sustainable intensification would be particularly efficient in areas where very low productivity systems, such as shifting cultivation in the Congo Basin, are replacing forests (Belassen and Gitz 2008). West (2010), comparing worldwide crop yields and carbon stocks, considers that concentrating reforestation and avoided deforestation in the tropics would have the greatest worldwide carbon sink effect with minimum opportunity costs in terms of crop yield.

Studies (Fischer *et al.*, 2009) have shown the importance in many developing countries of the yield gap. The yield gap is the difference between actual farm yields, as represented by the average yield achieved by farmers in a defined region over several seasons, and the potential yields which are the maximum achievable yield with latest varieties and by removing as much as possible all constraints as achieved in highly controlled stations. Reducing this gap is essential to improve food security and reduce deforestation.

Nutrients are essential to increase yields. But production of synthetic fertilizers is energy intensive, with a high cost in terms of CO_2 emissions and economic. In addition, when applied in the field, these fertilizers contribute to N_2O emissions. So, there is a need to improve fertilization and to limit the costs and the emissions at the same time. Improving fertilizer efficiency is thus essential. This can be done through a variety of techniques. One way is to match more precisely the nutrients with plant needs during the growing season, such as by fractioning the total amount in multiple doses. Other techniques include precision farming and placing nutrients closer to plants roots, such as deep placement of urea for rice (see box 1).

BOX 1: UREA DEEP PLACEMENT

Urea Deep Placement (UDP) technique, developed by the International Rice Research Institute (IRRI) and International Fertilizer Development Center (IFDC), is a good example of a climate-smart solution for rice systems. The usual technique for applying urea, the main nitrogen fertilizer for rice, is through a broadcast application. This is a very inefficient practice, with 60 to 70 percent of the nitrogen applied being lost, and contributes to GHG emissions and water pollution.

In the UDP technique, urea is made into "briquettes" of 1 to 3 grams that are placed at 7 to 10 cm soil depth after the paddy is transplanted. This technique decreases nitrogen losses by 40 percent and increases urea efficiency to 50 percent. It increases yield by 25 percent with an average 25 percent decrease in urea use.

UDP has been actively promoted by the Bangladesh Department of Agricultural Extension with IFDC assistance. In 2009, UDP was used on half a million hectares by a million farmers and there are plans to expand its use to 2.9 million more families on 1.5 million hectares.

The widespread adoption of the UDP technique in Bangladesh had several important impacts:

- Farmers' incomes have increased thanks to both increased yields and reduced fertilizers' costs.
- Jobs have been created locally in small enterprises, often owned by women, to make the briquettes. There are now 2 500 briquette making machines in Bangladesh.
- On-farm jobs have also been created as the briquettes are placed by hand, which requires 6 to 8 days labour per hectare. Higher yields the savings on fertilizer expenditures more than compensates for the additional field labour expenses.
- At the national level, imports of urea have been reduced, with savings in import costs estimated by IFDC at USD 22 million and in government subsidies of USD 14 million (2008), for an increase of production of 268 000 metric tons.
- At a global level UDP has reduced GHG emissions caused by the production and management of fertilizers.

It also increases the agricultural system's resilience. As fertilizers prices are linked to energy prices, and consequently very volatile, reducing fertilizer use also increases farm and country's resilience to economic shocks.

With the efficacy of the technique now well proven, UDP is being up scaled, partly through South/South cooperation. For instance, the National Programme for Food Security of Nigeria (NPFS) is supported by South/South cooperation with China. This support includes the promotion and development of the UDP technique in several Nigerian states.

Source: Roy & Misra 2003, Singh *et al.* 2010, Ladha *et al.* 2000, IFDC 2011

The inclusion of legumes in crop rotations exploits symbiotic microbes to fix nitrogen, which is harvested in the crop and partly transferred to subsequent crops increasing their yields. In forage legume/grass mixtures, nitrogen is also transferred from legume to grass, increasing pasture production. The protein content of legumes makes them important from a nutritional point of view. When included in livestock's feed, legumes increase the food conversion ratio and decrease of methane's emissions from ruminants, thus increasing efficiency and at the same time reducing GHG emissions. By providing proteins and the amino acid lysine, in which cereals are deficient, legumes complement cereals in human alimentation and reduce the need for animal proteins. Unfortunately, the global area under pulses dropped from approximately 5 million hectares in 1968 to 3.9 million in 2007. Globally, consumption of pulses in terms of kilocalories per capita per day also dropped from 73 in 1968 to 57 in 2007.

Sustainable intensification of crop production (see box 2) aims to increase yields through the better use of natural resources and ecosystems functions.

BOX 2: SAVE AND GROW – MORE SUSTAINABLE INTENSIFICATION

Sustainable crop production intensification (SCPI) can be summed up in the words "save and grow". Sustainable intensification means a productive agriculture that conserves and enhances natural resources. It uses an ecosystem approach that draws on nature's contribution to crop growth – soil organic matter, water flow regulation, pollination and natural predation of pests – and applies appropriate external inputs at the right time, in the right amount to improved crop varieties that are resilient to climate change and use nutrients, water and external inputs more efficiently.

Sustainable intensification of crop production is achievable. This can be done through increasing resource use efficiency and cutting the use of fossil fuels. This saves money for farmers and prevents the negative effect of over-use of particular inputs. Inefficient fertilizer use is common in certain regions. In some cases, this is a consequence of government subsidies. Yet over-use does not have the intended impact on plant growth and can result in the contamination of ground and surface water. Inappropriate insecticide use may actually induce pest outbreaks by disrupting the natural population of predators. Overuse of herbicides can lead to the emergence of herbicide-tolerant varieties of weeds. Problems of salinization or reduced soil health may also come from inappropriate management practices, such as irrigating without proper drainage. Better maintenance of ecosystem services can be accomplished through agricultural practices that are based on crop rotations, use minimum tillage and maintain soil cover; rely on natural processes of predation or biocontrol for pest or weed problems; manage pollination services; select diverse and appropriate varieties; and the carefully targeted the use of external inputs. These practices are knowledge-intensive and they are often also interdependent. In the initial stages, encouraging these practices may require public support through targeted incentives and investment. Ideally, the price of agricultural commodities would increasingly reflect the full cost of production, including the potential damage done to natural ecosystems, thereby encouraging consumption of more sustainably produced food.

Source: FAO 2011b

3.1.3 Increase resource efficiency in livestock production

The livestock sector has expanded rapidly in recent decades and will continue to do so as demand for meat, eggs and dairy products is expected to continue grow strongly, especially in developing countries. Already, livestock grazing occupies 26 percent of the earth's ice-free land surface, and the production of livestock feed uses 33 percent of agricultural cropland (Steinfeld et al. 2006). There is an urgent need to improve the resource use and production efficiency of livestock production systems, both to improve food security and reduce the intensity of GHG emissions (FAO 2009a, HLPE 2012a). These efforts need to take into account the growing dichotomy between livestock kept by large numbers of small holders and pastoralists and those kept in intensive systems. A study on cow milk (Gerber *et al.*, 2010) shows that the emissions per litre of milk are dependent on the efficiency of the cows: the more efficient the cows, the fewer emissions per litre of milk. This increased efficiency should be pursued in all possible ways, from livestock selection and nutrition to manure management.

Selection to improve efficiency and thus reduce GHG emission of livestock systems involves numerous parameters, including productivity per animal, early maturity, fertility, feed conversion rate and longevity. In controlled environments, breeding for high performance has already resulted in significant reductions in the amount of feed per unit of product, especially for monogastrics and dairy cattle. The challenge is now to also improve productive parameters in more diverse environments (Hoffmann, 2010).

Improving animal health has a strong impact on the efficiency of livestock systems, food security and climate change. Establishing strong veterinary institutions and policies are essential both to improve livestock efficiency and increase the preparedness against new risks, including those that result from climate change.

Nutrition plays a critical role in making a livestock production system more efficient. Proper nutrition is imperative for achieving high reproductive efficiency in animals, protecting them from diseases and making animal health interventions more effective. Imbalanced feeding leads to productivity losses and increase in emission of green house gases, either as CH4 from enteric fermentation in ruminants (between 2 - 12 percent of feed energy is lost in the form of methane) or as CH_4 and N_2O produced from manure. A balanced diet enhances animal performance and reduces GHG emissions per unit of animal product. Efficient nutritional strategies for monogastrics (pigs and chickens) include matching nutrient contents in feeds (taking into consideration both their level and availability to the animal) to the physiological requirements of animals; selecting feeds with high nitrogen availability in the animal body; and optimizing proteins and amino acids in diets to improve the feed conversion to animal products. For ruminants, techniques such as a) feeding of: diets balanced for nitrogen, energy and minerals - preferably as total mixed rations; chaffed forages, preferably of high quality; chaffed and water-soaked straws or urea-ammoniated straws; and grains- and b) use of feed additives, - e.g. ionophores, probiotics, enzymes, oils including essential oils, some tannins and saponins- can be used either to improve the feed conversion ratio and/or to specifically reduce methane emission and nitrogen release into manure.

Improving pasture productivity and quality, either by improving the composition of forage, especially in artificial pastures, and by better pasture management is an important means to improve food security, adapt to climate change and reduce both direct and indirect GHG emissions. Supplementing poor quality forages with fodder trees, as in silvo-pastoral systems, or with legumes, increases its digestibility, thereby improving the production efficiency of livestock and decreasing methane emissions. The introduction of legumes in pastures also increases forage production and reduces pressure on forests without a corresponding increased use of fertilizers. Improved grazing management could lead to greater forage production, more efficient use of land resources, enhanced profitability and rehabilitation of degraded lands and the restoration of ecosystem services. Grazing practices, such as setting aside, postponing grazing while forage species are growing, or ensuring equal grazing of various species can be used to stimulate diverse grasses; improve nutrient cycling and plant productivity and the development of healthy root systems; feed both livestock and soil biota; maintain plant cover at all times; and promote natural soil forming processes.

Manure management is important both to increase food security and to mitigate climate change as it can be used as organic fertilizer and is also a source of CH_4 and N_2O emissions. When manure is used as organic fertilizer it contributes to the productivity and fertility of the soil by adding organic matter and nutrients, such as nitrogen, that are trapped by bacteria in the soil. It improves productivity and allows for reductions in use of synthetic fertilizers and the associated direct and indirect GHG emissions. The increasing geographic concentration of livestock production means that the manure produced by animals often exceeds the (nitrogen) absorptive capacity of the local area. Manure becomes a waste product rather than being the valuable resource it is in less concentrated, mixed production systems. Proper use of technologies can reduce direct emissions and also transform manure into a valuable resource and lead to a corresponding reduction in GHG emissions resulting from the use of synthetic fertilizers.

BOX 3: PARTNERSHIP ON BENCHMARKING AND MONITORING THE ENVIRONMENTAL PERFORMANCE OF LIVESTOCK SUPPLY CHAINS

Quantitative information on key environmental impacts along livestock supply chains is required to (a) analyse food systems and inform decisions at the production and processing levels to improve environmental performance; (b) develop and evaluate corresponding policy decisions (governmental and non-governmental); and (c) inform relevant stakeholders.

Valuable work aimed at improving the measurement of environmental performance is being carried out by the livestock industry, governments, academia and non-governmental organizations (NGOs). However, inconsistencies in the methods used and the one-off nature of many of the studies does not provide consistent guidance on the required changes in practices and the potential efficiency gains that can be achieved. Consultations with stakeholders during 2010 and 2011 confirmed that there was demand for a partnership on benchmarking and monitoring the environmental performance of the livestock sector. A participative formulation process led to the identification of key functions and deliverables of the Partnership. It was agreed that representatives of private sector, NGOs, governments, science and international standard organizations should be involved.

The Partnership's objective is to improve environmental performance of the livestock sector, while considering its economic and social viability. This will be achieved through support to decision-making and by providing guidance on performance assessments (metrics and methods) and their use. Activities are structures along four components:

Component 1 – Sector-specific guidelines and methods for the life cycle assessment of GHG emissions from livestock food chains;

Component 2 – Global database of GHG emissions related to feed crops;

Component 3 – Measures of non-GHG environmental performance of livestock food chains; and

Component 4 – Communication strategy.

Further information on the Partnership is available at: http://www.fao.org/ag/againfo/home/en/news_archive/AGA_in_action/2011_livestock_food_chains.html

Source: Pierre Gerber, Michael MacLeod, Carolyn Opio and Henning Steinfeld FAO, Animal Production and Health Division (AGA), Livestock information, sector analysis and policy branch (AGAL)

3.1.4 Integrated systems

Crop systems and livestock systems can also be improved by better integration between them. Integrated crop and livestock systems, at various levels of scale (on-farm and area-wide) increase the efficiency and environmental sustainability of both production methods. When livestock and crops are produced together, the waste of one is a resource for the other. Manure increases crop production and crop residues and by-products feed animals, improving their productivity. In these systems, livestock is a strategic element for adaptation. The animals provide an alternative to cropping in areas becoming marginal for cropping, offer a way to escape poverty and represent a coping mechanism in variable environment. They also constitute capital that can be converted to cash when needed.

Rice-Fish integrated systems are another example of very productive systems that also provide more balanced diets.

Agroforestry is the use of trees and shrubs as part of agricultural systems. It contributes to prevent soil erosion, facilitates water infiltration and diminishes the impacts of extreme weather. Agroforestry also helps diversify income sources and provides energy and often fodder for livestock. Nitrogen-fixing leguminous trees, such as *Faidherbia albida*, increase soil fertility and yields (Bames and Fagg, 2003; Garrity, 2010)). Thanks to development and community-led projects and relaxed forestry measures that enable farmers to manage their trees, there has been a considerable development of *Faidherbia* in Niger through farmer-managed natural regeneration (Garrity, 2010). Since 2000, FAO has initiated special programmes for food security with the governments of Guatemala, Honduras, Nicaragua and El Salvador (see box 6). These programmes work together, sharing practices, experiences and results to improve and develop agroforestry systems. Agroforestry systems are promoted in the subregion as a substitute to traditional slash-and-burn systems, particularly on slopes. Under these systems, productivity of land and labour are increased. Yields are less variable, partly thanks to better retention of moisture in the soils. The soil is also protected from hydric erosion. Farm production, including wood products, is more diversified, which stabilizes incomes. As they are more efficient in the use of land, agroforestry reduce the pressure on forests, which contributes to climate change mitigation. As wood is produced in the fields, these systems also contribute to preventing forest degradation. Agroforestry systems use less fertilizer, which reduces the direct emissions of N_2O and indirect GHG emissions created through fertilizer production. By increasing biomass above ground and in soils, they help create carbon sinks.

There is now interest for using carbon projects to facilitate the development of agroforestry. Examples include the Nhambita community carbon project in Mozambique, initiated in 2003. A small-scale agroforestry-based carbon sequestration project, registered with the Plan Vivo system, it has been under implementation in Nhambita since 2003. The project's objective is to sequester carbon through agroforestry practices, sell carbon credits in international voluntary carbon markets and improve livelihoods in the local community. The Community Association, the body established in 2002 by the Rural Association for Mutual Support (ORAM) as a part of a national government programme to regularize traditional community's tenure rights, helps to identify the households that wish to become part of the agroforestry scheme and is responsible for the management of the carbon payments, which are transferred into community fund (Spirik 2009).

3.1.5 Reduce food losses and waste

Food losses and waste are considerable. These losses and waste also mean that the GHG emitted for their production have served no useful purpose. This is especially true when the food has reached the end of the food chain, when the embedded emissions for transport and conservation are very high.

Global differences among regions in food loss and waste for the same type of products indicate potential areas for improvement (Gustavsson et al. 2011). In Europe, cereal losses and waste are twice as high as in sub-Saharan Africa. On the other hand, in sub-Saharan Africa, milk losses and waste are twice as high as in Europe.

Depending on the products and the regions, the distribution of the losses along the food chain is very different. For instance, in Africa cereals are lost in the first stages of the food chain. In Europe, they are lost mostly at the consumer stage: 25 percent against 1 percent in Africa. For fruits and vegetables, the differences between regions are also striking. In Africa, processing and distribution are the weak links. This highlights the need for investments in these stages of the food chain. In Europe, it is at the production and consumption stages where most losses occur.

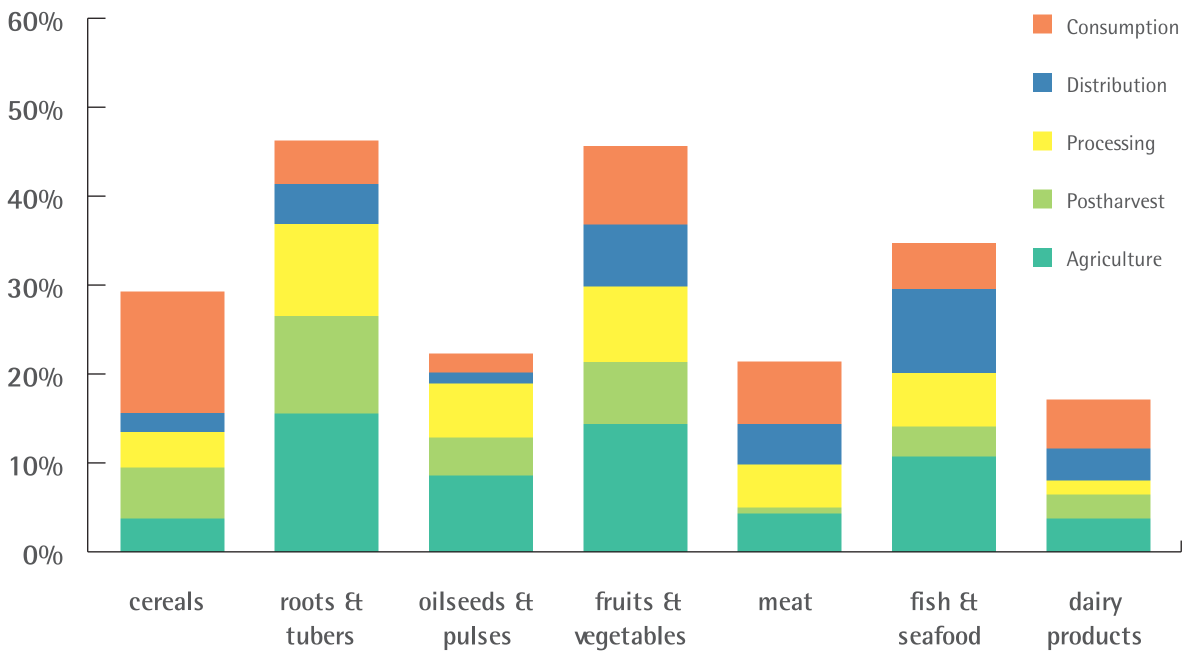

Figure 1.

Source: adapted from Gustavsson *et al.* 2011

However, there are techniques available to reduce food losses. One example are household metal silos for conservation of cereals or tubers, which have been actively promoted by various organisations, including FAO and NGOs. The use of metal silos in Afghanistan has reduced storage loss from 15-20 percent to less than 1-2 percent. They are manufactured locally, which creates jobs, small enterprises and possibilities for diversification of the local economy. The silos enable farmers to preserve food, making producers less vulnerable, either as sellers or buyers, to price fluctuations on local markets.

In developed countries, waste at the retail and consumption stages is extremely significant. Reducing this waste requires behavioral changes and the involvement of all concerned stakeholders, governments, private sector and civil society.

BOX 4: THE SAVE FOOD GLOBAL INITIATIVE

In May 2011, FAO's Agriculture & Consumer Protection Department organized the international congress 'Save Food!', in partnership with Interpack/Messe Düsseldorf – a global player on trade fair organization, including the food and packaging industry. Speakers, stakeholders and high-level policy makers in the agriculture, food and packaging sector from across the globe, signed a joint declaration to show their commitment to the goals of Save Food. The partnership instituted the SAVE FOOD Initiative, which is a joint campaign to fight global food losses and waste. The Initiative aims at networking among stakeholders in industry, politics and research, encouraging dialogue and helping to develop solutions to food losses and waste along the food value chain. One of its objectives is to enlist the support of industry in initiating and sponsoring its own SAVE FOOD projects.

Source: http://www.fao.org/save-food/save-food-home/en/
http://www.save-food.org/

All along food chains, from agricultural production, transport, conservation, processing, cooking and consumption, there are potential areas for improving energy efficiency (FAO 2011c). In Africa, 90 percent of the extracted wood is used for domestic purposes, mostly cooking. Improved energy saving cooking stoves can contribute to reduce deforestation. However, trade-offs may need to be made between reducing losses and reducing energy consumption, especially for fresh perishable products, such as meat, dairy products, fish, fruits and vegetables. Consumption of perishable products, which often require cold chains and rapid transport, is increasing. Analyses of food losses and waste should therefore encompass the whole food chain to be able to consider all impacts and all potential solutions. For instance, processing fresh products transported over long distances into less perishable products can reduce foods losses and GHG emissions resulting from conservation and transport, as slower methods of transport can be used.

3.1.6 System efficiency

A change of practice in one component of a given system generally impacts the whole system. So it is not only a single technique or practice that has to be considered but the system as a whole, at the farm and household level and beyond the farm gate. Box 1 provides an example of the various consequences of the introduction of the UDP technique in Bangladesh.

Most of the changes in resource use of one factor of production impacts the use of other factors. Therefore, from a 'GHG efficiency' perspective, we need to assess the trade-offs between increasing resource efficiency regarding one or another input, for example, increasing yield per hectare through increased use of fertilizers. Thus, for improvements involving variations of several 'emitting' factors, a comprehensive assessment is needed, using life cycle analysis methodologies or GHG accounting tools.

As seen in the example of UDP in Bangladesh (Box 1) changes towards more resource efficiency, even through the introduction of a single new technique, can have major economic and social impacts which, in turn have impacts on food security, especially in terms of access to food. Whatever the 'efficiency' considered, there is a need to look at the question of allocation of factors and at the issue of scale. Indeed, production efficiency, GHG-efficiency, economic efficiency and food security efficiency do not always go hand in hand. For instance, to increase the part of workforce in the mix of factors of production might go against economic efficiency at the farm level, but may have a positive effect on food security. In that respect, efficiency should be assessed inside a system, at various scales and from various perspectives.

3.2. More resilient systems[4]

Climate change will profoundly modify, in any given place, the conditions under which agricultural activities are undertaken. It will modify existing risks and add new risks and uncertainties. As pointed out by the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2012a) models cannot project climate change effects precisely, neither in time nor at the local scale needed for decision makers. Moreover, climate models do not deal with the consequences of increased variability, the impacts of stress combinations, the effects of climate change on whole agro-ecosystems, including crops, their pests and predators of these pests. As it is impossible to predict exactly these changes, it is often difficult to devise precise adaptation measures and even more difficult to promote them. One of the most effective approaches to get prepared for uncertainty and new risks – a 'no regret' approach that is valid whatever changes happen – is to reduce vulnerability and increase resilience of a given system (FAO/OECD, 2012; HLPE, 2012a).

3.2.1 Risks

Agricultural production is submitted to risks of various types: economic and price-related risks, climatic, environmental, pests and diseases, at different scales, and, often also, political instability. Yield risk in main staple crops is particularly important for smallholders who tend to consume a large part of their own production. Farmers are also exposed to economic risks, including land tenure insecurity, variations in access to inputs (fertilizers, seeds, pesticides, feed) in quantity and quality and variations in access to markets.

'Risk' is used here to designate the potential of shocks and stresses to affect, in different ways, the state of systems, communities, households or individuals. Probability, uncertainty (when probabilities of occurrence or even nature of impacts are unknown), severity, economic scale, time scales and direct and indirect costs should be taken into account.

Risks affecting agricultural activities are generally categorized according to the nature of the associated shocks (e.g. biophysical, economic) (Eldin M. et Milleville P., 1989; Holden *et al.*, 1991; Cordier,

4 This section draws heavily on Gitz V. & Meybeck A. 2012. Risks, vulnerabilities and resilience in a context of climate change. FAO/OECD Workshop: Building Resilience for Adaptation to Climate Change in the Agriculture Sector, Rome, Italy, 23-24 April 2012.

2008; OECD, 2009). They are also often classified according to the intensity, frequency and predictability (degree of uncertainty) of the associated shocks. They can be also categorized according to their impacts and their nature, as well as their importance and scope both in space and time (INEA, 2011). Weather is in itself a major cause of risk and also has a major influence on other types of risks. Climate change is expected to modify the nature, extent and intensity of these risks, plant pests, animal diseasesdisruption of ecosystem functions (HLPE, 2012a; FAO/OECD, 2012).

The impact of a risk depends on the shock itself and on the system that receives the shock. Depending on its vulnerability, the system will be more or less affected by the same shock. Depending on its resilience, the system will recover more or less easily.

Food systems are by nature ecological, economic and social (Ericksen, 2008; Fussel & Klein, 2006). Each dimension has its own organization and interacts with the others. Food systems can be described and analyzed in each of their dimensions. There are also theories attempting to understand and describe 'complex systems' (Holling, 2001; Gunderson and Holling, 2001) to obtain better grasp of the concept of sustainability.

Even when considering a single simple farming system, a single stress or shock can have various impacts of diverse nature, and time scale. The global impact of a shock often also depends on the transmission of its effects from one dimension (biophysical) to the others (economic and social) and from one level (household) to another (community).

For instance, a drought in livestock grazing systems (see Fig. 2) reduces the availability of water and grass – both directly and indirectly because as the watering points are reduced some pastures are no more accessible- and so increases the demand for feed at the very moment when there is less feed available. Increased demand drives a feed price increase, which forces livestock owners to sell their cattle. Massive sales while there is a reduced demand pushes down cattle prices, forcing livestock owners to sell even more to buy feed. These effects on prices reduce farm and household income and assets. Moreover, they reduce the value of assets (livestock) and productive capital for the future. Prolonged or repeated drought also has long-lasting degrading effects on land. The combination of drought and overgrazing, particularly near watering points, destroys the vegetal cover and increases soil erosion.

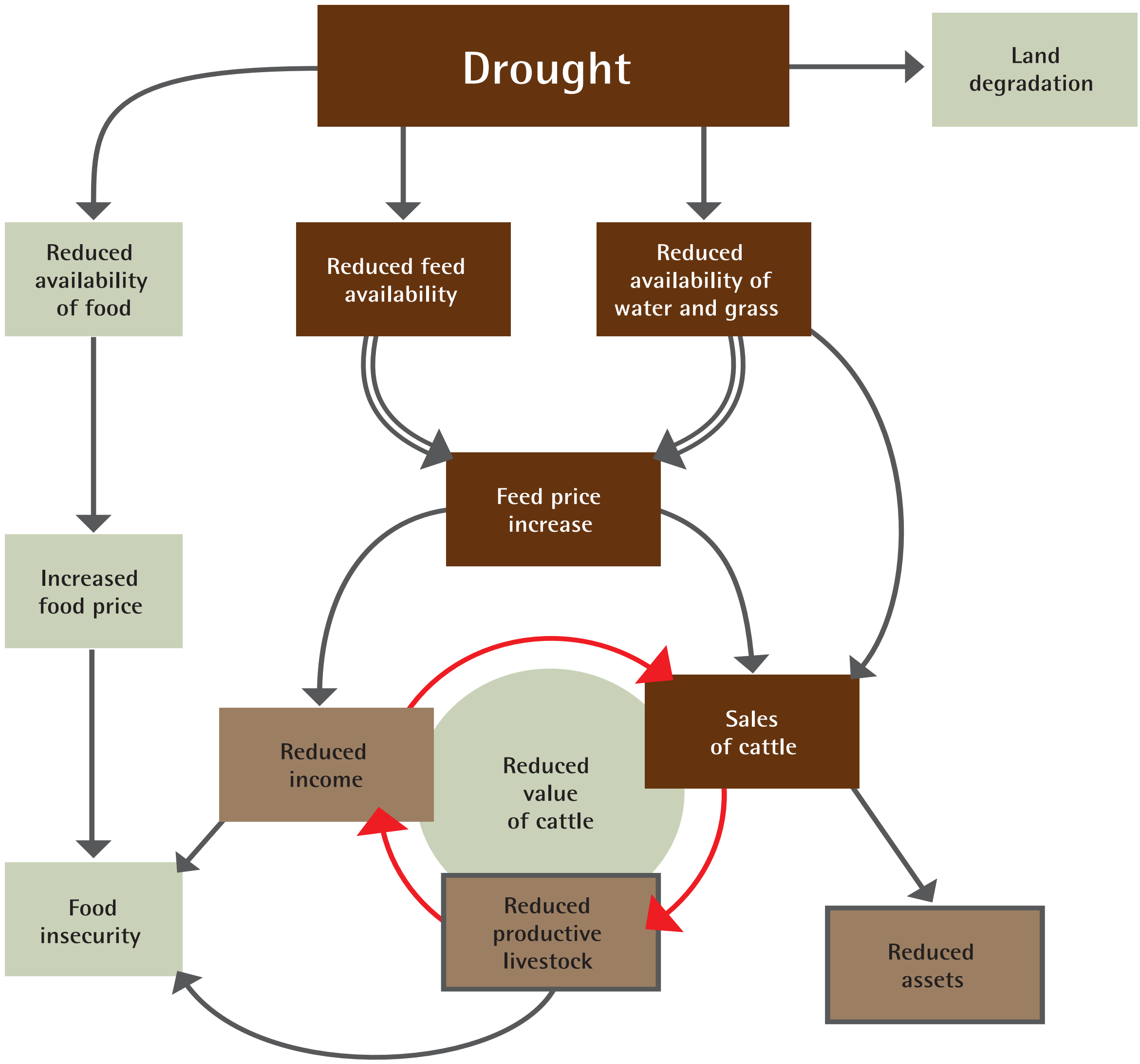

Figure 2 : Impacts of drought

Source: Gitz and Meybeck 2012

3.2.2 Vulnerabilities

The net impact of a shock depends not only on the intensity of the shock itself but also on the vulnerability of the system to this particular type of shock.

Vulnerability can be defined as the propensity or predisposition to be adversely affected (IPCC, 2012). It is a complex concept (Fellmann 2012) that needs to be considered across scales and across various dimensions (Gitz and Meybeck 2012). It can be defined as vulnerability of 'what' to 'what' (Carpenter *et al.*, 2001).

The degree of 'specific' vulnerability of a system to a particular type of risk can be analysed as exposure and sensitivity to the potential shock that relates to this risk, and also depends on the 'adaptive capacity' of the system to cope with the impact of the shock. The adaptive capacity itself can also be affected by an external shock. In a given system, shocks in one dimension can spread into another dimension. For example, production shocks can be transmitted to the economic and social domains. This transmission can be linear, amplified or reduced, depending on the policies and institutions that are in place.

In many cases, there can be amplifying or positive correlations between the effects of shocks of diverse nature. In such cases, reducing vulnerability to one kind of shock can help also to reduce (specific) vulnerability to another kind of shocks. Vulnerability is also affected by the various shocks (e.g. a drought increases vulnerability to the next drought). By decreasing the strength of the cattle, drought also increases their vulnerability to diseases. By reducing assets of households, drought also increases their vulnerability to any kind of shock.

Systems can be defined at various scales. An upper-scale system is generally composed of different systems defined at lower scales. For instance, from a biophysical perspective, landscape systems are composed of farm systems. The vulnerability of an upper-scale system depends on the vulnerability of the subsystems that it includes. It also depends on how other systems to which it is linked, including higher-scale systems, are vulnerable or insensitive to shocks. For example, the vulnerability of a farm to a certain risk is compounded by its own vulnerability and the vulnerability of the landscape in which it is situated, and whose vulnerability is in turn compounded by the vulnerabilities of the various farms situated in it and by the vulnerability of the higher-level system (e.g. the territory) in which it is situated.

3.2.3 Resilience

Resilience can be described as the capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk and recover from shocks. At first approximation, resilience is the opposite of vulnerability. However, resilience adds a time dimension. A system is resilient when it is less vulnerable to shocks across time and can recover from them. Essential to resilience is adaptive capacity. Adaptive capacity encompasses two dimensions: recovery from shocks and response to changes in order to ensure the 'plasticity' of the system.

For example, the organization of proper seeds systems enables farmers who have lost a crop to have seeds for the next season. It also enables them to have access to seeds that are adapted to new conditions.

As for vulnerability, resilience can be specified as "resilience of what to what" (Carpenter *et al.,* 2001). However, focusing on specified resilience may cause the system to lose resilience in other ways (Cifdaloz *et al.*, 2010). This is why general resilience can be described as being "about coping with uncertainty in all ways" (Folke *et al.*, 2010).

And as for vulnerability, resilience can be considered in various dimensions (biophysical, economic and social) and at various scales. The way the various dimensions and scales interact is crucial, precisely because of the importance of general resilience for coping with uncertainty. For instance, Karfakis (2011) shows that increasing the level of education of farmers can be an efficient mean for reducing farmers' household vulnerability to climate change.

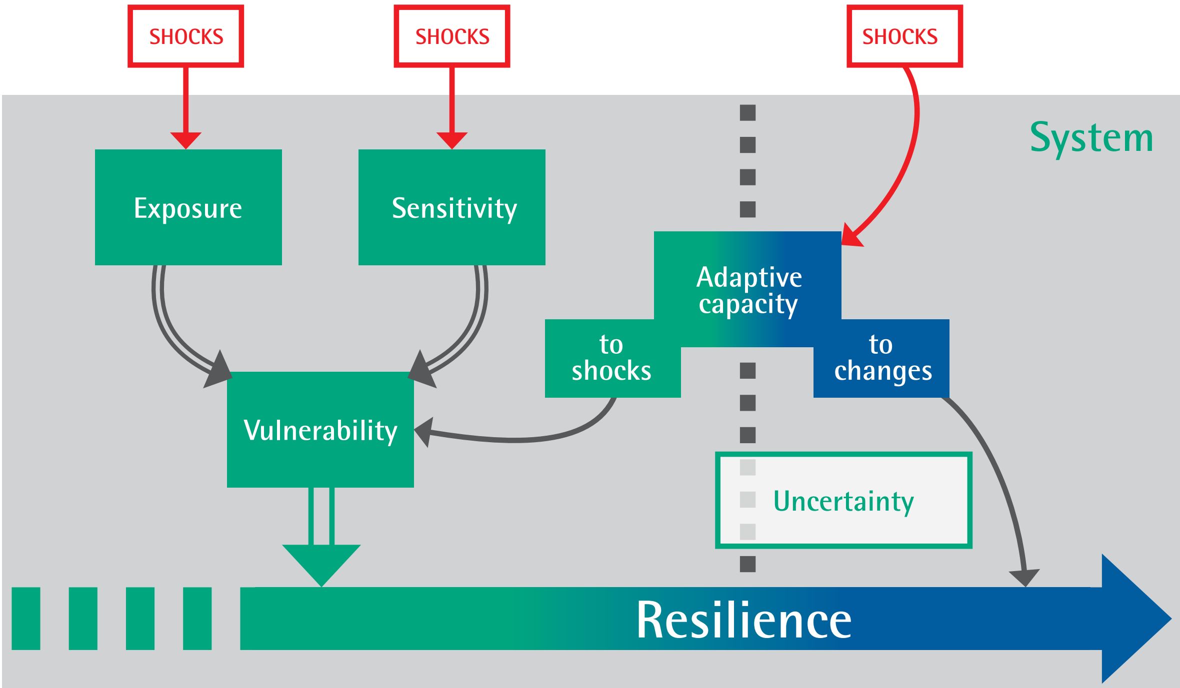

Figure 3 : Components of resilience

Source: Gitz and Meybeck 2012

Resilience puts a greater emphasis on the capacity of a system to recover and transform itself over the long term, and adapt to its changing environment in a dynamic perspective. It implies that it is not only shocks, as a change relative to an average, that have to be considered, but also the change of the average itself. Ultimately, the question is until what point can a system adapt before changing to another type of system.

3.2.4 Building resilience

To a great extent increasing resilience can be achieved by reducing vulnerabilities and increasing adaptive capacity. This can be done by reducing exposure to risk, reducing sensitivity and increasing adaptive capacity for every type of risk. It can act in each domain, either bio-physical or economic and social. One way to achieve better resilience is to reduce transmission of shocks between types of risks, between scales and between domains and to organize compensation between scales (for instance transport of feed) or between domains (for instance safety nets) to avoid cumulative and long-term effects.

In a first approximation we can identify the following three ways to build resilience:

1 - Reduce exposure. There is a fundamental difference between climatic and non-climatic shocks in this regard because most of the shocks on farm can be reduced at the source, or limited in their extension, contrary to climatic shocks. The best example is probably the eradication of Rinderpest, which has totally suppressed a major risk for livestock and those depending on it.

2 - Reduce the sensitivity of systems to shocks. Sensitivity to drought can, for instance, be reduced by using drought-resistant varieties or keeping stocks of hay.

3 - Increase adaptive capacity. This includes considering the modifications of a system and taking into account all the potential shocks and changes together (to take into account compensating, cumulative or exacerbating effects).

Finally, we have to consider that the occurrence of shocks is not certain. The own nature of the shock may be uncertain as well as the nature or size of its impacts. In addition, their occurrence in time is generally not known. Therefore, building resilience goes hand in hand with the need to anticipate within uncertainty, within the system, or across scales. In that sense, specific risk monitoring not only reduces vulnerability but also increases resilience as it allows for the anticipation of risks and their changes.

BOX 5: PREVENTION OF MAJOR DESERT LOCUST UPSURGES IN WEST AND NORTHWEST AFRICA

Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES Programme)

The Desert Locust is a highly destructive transboundary plant pest that threatens people's livelihoods, food security, the environment and economic development in more than 30 countries. In terms of bio-ecology, West and Northwest Africa (Western Region) is an indivisible distribution area of this pest. In that area more than 8 million people faced severe food shortage as a result of the 2003-2005 Desert Locust major upsurge (Brader *et al.*; 2006). It cost the international community and affected countries over USD 570 million to overcome it and 13 million litres of chemical pesticides were applied. The Sahelian countries also suffered from high crop losses ranging from 30 to 100 percent.

To address the Desert Locust issue more effectively, the Western Region countries (Algeria, Burkina Faso, Chad, Libya, Mali, Morocco, Mauritania, Niger, Senegal and Tunisia) set up in 2002 the Commission for Controlling the Desert Locust in the Western Region (CLCPRO) under the aegis of FAO. To implement a sustainable preventive control strategy, they also joined the FAO EMPRES Programme, launched in 2006 in the Western Region.

The Evaluation Missions of Phase 1 (2006-2010) of this Programme (Cossé et al. 2009 et Risoli, 2009) underlined that substantial progress had been made in achieving the objectives, in particular, in the frontline countries (Chad, Mali, Mauritania and Niger) in terms of: institutional building with the creation of autonomous National Locust Control Units (NLCUs); strengthening of locust control capacities and infrastructure; implementation of early warning system and rapid interventions, health and environmental standards developed and better preparedness to Desert Locust crises (ongoing contingency planning). The improvement of more effective preventive control strategy became obvious during the control operations against locust outbreaks in 2006, 2008, 2009 and 2010-2011 in Mauritania and in 2009 in Niger. Also, a gradual funding of the recurrent costs for preventive control implemented by of the NLCUs from the national budgets was observed: from 10 percent in 2006, it reached an average of 60 percent in the frontline countries at the end of 2010.

The annual cost of preventive control in the Western Region is USD 3.3 million, less then 0.6 percent of the expenses incurred during the 2003-2005 major outbreak.

A good example of actions to build resilience in the face of uncertainties due to climate change can be found in the domain of genetic resources (HLPE, 2012), and the topic is being considered by the Commission on Genetic Resources for Food and Agriculture (CGRFA)[5]. If climate changes, farmers might need to rely on different genetic resources, some that are already used elsewhere, or others species or varieties that are considered minor but that may be better adapted to new conditions. To do so, there is the need to be able to have access to the largest possible pool of genetic resources. Genetic resources, which are also threatened by climate change, are indispensable for adaptation. We need to preserve diverse genetic material, including traditional and improved crop varieties and their wild relatives. They are adapted to specific conditions, have been selected

5 The Secretariat of the Commission on Genetic Resources for Food and Agriculture has commissioned and prepared several background papers (No 48, 53, 54, 55, 56, 57, 60) on climate change and genetic resources available at http://www.fao.org/nr/cgrfa/cgrfa-back/en/?no_cache=1.

for different uses, and constitute the reservoir from which varieties can be developed to cope with effects of climate change, such as drought, the shortening of the growing season, increased incidence of pests and diseases. Preserving genetic resources increases the resilience potential of the whole system. To achieve this, the potential effective genetic resources have to be accessible to farmers where they are needed. It is not enough to have the appropriate genetic resources in a genebank or a research centre. They have to be multiplied and distributed, which requires plant breeders, seed enterprises and the proper legal system to certify their quality and the accuracy of the genetic information. All these actors and elements constitute 'seed systems', which enable farmers to have the seeds they need. Regional harmonization of seed rules and regulations is also essential, particularly as crops will move to adapt to climate change (Burke et al 2009).

In agroforestry systems the various dimensions and scales interconnect to increase the resilience of farming systems.

BOX 6: A CHANGE OF SYSTEM: FROM SLASH AND BURN TO AGROFORESTRY IN CENTRAL AMERICA

Since 2000, FAO has initiated special programmes for food security with the governments of Guatemala, Honduras, Nicaragua and El Salvador. To improve and develop agroforestry systems in the subregion, these programmes worked together, sharing practices, experiences and results. Agroforestry systems are promoted as a substitute to traditional slash-and-burn systems, particularly on slopes. They are at the same time more efficient and resilient.

In traditional slash-and-burn systems, a family needs close to 6 hectares to maintain itself on a diet of corn and beans. The family exploits the parcel for two years and then sets it aside for 14 years. In agroforestry systems a parcel is exploited for 10 years, producing, along with corn and beans a variety of other products, often including livestock. The parcel is then is set aside for only 5 years. A family thus needs 1.4 hectares to sustain itself and enjoys a more varied and balanced diet. Land is therefore almost 4 times more efficient. Efficiency also increases because in agroforestry systems, yields (which are comparable the first year) do not decline over time as they do very rapidly in slash-and-burn systems. In fact, yields can even increase slightly over time in agroforestry systems. Productivity of labour and of capital is also higher in agroforestry systems. Costs are reduced, especially for fertilizers, thanks to more organic matter in the soil and better use of nutrients by the plants. At the community level, diversification of productions triggers the development of local markets. Conseqently in terms of resource use, agroforestry systems are efficient safeguarding food security and the environment.

Agroforestry systems are also much more resilient:

- Yields are less variable thanks to better humidity retention.

- They provide for more diverse productions, which provides a buffer against both the variability of crop yields and price volatility.

- They offer diversified sources of income, including through selling wood for various uses (and at various time scales), which can also provide a buffer against some economic shocks.

- They protect the soil from erosion, which is a major concern in these areas. Studies have shown that in agroforestry systems erosion is reduced by a factor of more than 10.

Source: FAO 2010d

Sustainable management of forests (Braatz, 2012) and sustainable management of fisheries (De Young 2012) are good examples of where the actions towards increasing resilience in one domain of vulnerability, starting with the biophysical domain, also have positive effects on the resilience and vulnerability in other domains (social and economic). Landscape approaches can play an essential role in building resilience (HLPE, 2012a).

Social protection can play an essential role in increasing resilience at household and community level. This is especially true if national systems are designed as comprehensive programmes that exploit the synergies between various instruments in such a way as to cover the specific needs of various groups, especially the more vulnerable, and to be easily scaled up to address any kind of shock (HLPE, 2012b).

The notion of resilience is particularly powerful for bringing together interventions that cover different dimensions. Improving the sustainability of forest management not only increases the forest's resilience, it also contributes to improving water management, protecting the soil from erosion and to conserving agrobiodiversity (e.g. by providing habitat to pollinators). In this way, improvements in the sustainability of forest management contribute to improving the resilience of farming systems. As mentioned earlier, landscape approaches can play an important role in that respect (HLPE, 2012a). Forestry and fisheries provide complementary food and income and in so doing contribute to improving the resilience of households and food systems. The notion of resilience also helps clarify the relations between 'specific' vulnerabilities and resilience and how addressing known risks can allow for the creation of strategies to build general resilience to cope with uncertainty. As such, resilience provides an efficient way for implementing 'no regret' adaptation. A crucial element would be to better manage known risks, whether climatic or not, to increase preparedness to future, uncertain risks and changes.

3.3 Efficiency and resilience

Efficiency and resilience should be pursued together and at various scales in agricultural systems and food chains. Being efficient without being resilient will not be helpful over the long term, given that shocks will occur more often. Being resilient without being efficient or without allowing for an increase in production, will pose problems for ensuring food security over the long term and for supporting livelihoods. In the pursuit of these two goals, there might be trade-offs, but there will also be synergies. Increasing efficiency could lead to greater sensitivity to certain shocks. For example, more productive livestock is more sensitive to heat waves (Hoffmann, 2010). On the other hand, increased efficiency can be a factor in increasing resilience. For example, increasing production in food importing countries will improve their resilience to price volatility. Increasing soil carbon stocks, enhancing diversity in the field and improving trade are of particular interest with regard to improving efficiency and resilience of food systems.

3.3.1 Increasing soil carbon stocks

Increasing soil organic carbon improves both efficiency and resilience. It improves nutrient and water intake by plants, which increases yields and resource efficiency of land, nutrients and water. It also reduces soil erosion and increases water retention, especially as it is often combined with added soil cover, as in conservation agriculture. This combination makes the system more resilient to variability of precipitation and to extreme events. Increasing carbon sinks in the soils also captures carbon, which contributes to climate change mitigation. For all these reasons, restoring degraded lands and increasing the level of organic carbon in soils is a priority action (IPCC, 2007b; FAO, 2009b; FAO, 2010a; HLPE, 2012a).

3.3.2 Increasing diversity in the field

Increasing diversity of production at farm and landscape level is an important way to improve the resilience of agricultural systems (FAO, 2010a; FAO-OECD, 2012; HLPE, 2012a).

Specialized systems are often presented as being more efficient from an economic point of view, as they generate more income. These systems can benefit from the improved technologies and from economies of scale in the production and distribution of inputs, machines, and especially processing and trade.

Diversifying production can also improves efficiency in the use of land. as is the case in agroforestry systems for instance and of nutrients as by the introduction of legumes in the rotation or in integrated crop/livestock or rice/aquaculture systems. Studies show that they can also be more efficient in terms of income (see for instance box 6), especially if this is measured as an average over a period of several years. The Finnish project ADACAPA aims to identify means for assessing and enhancing the adaptive capacity of the Finnish agricultural sector to global environmental and socio-economic changes at various decision-making levels (farm, regional, national). The main hypothesis tested is that increasing diversity enhances resilience and thus adaptive capacity of agrifood systems. Some of the results of studies conducted in the ADACAPA project have shown that diversity can increase income (Kahiluoto 2012). Farms that both grow crops and exploit forest generate a higher and more stable income. Regions growing more diverse varieties of barley have a higher average yield than areas growing a single variety. More diversified systems can also spur the development of local markets. An example of this is agroforestry in Central America (box 6). Finally, systems providing more diverse types of food are also more efficient from a nutritional point as they facilitate more balanced and diverse diets.

3.3.3 Trade

Agriculture is a classical example that illustrates the role of trade to increase global economic efficiency by exploiting local comparative advantages. This has been questioned from a GHG emissions perspective, initially triggered by the promoters of the 'food miles' concept who advocate the consumption of local products to reduce GHG emissions. In reality, transport represents a small part of global food systems' emissions. Emissions from transport are estimated by Weber & Matthews (2008) to be 11 percent, of which 6 percent results from consumers' transport to buy food. Life cycle analysis of various products confirm that, apart from fresh fragile products, such as fish, fruits and vegetables, transport is not the determining factor of their carbon footprint (FAO, 2012c). In fact, a more efficient production system can more than compensate for the emissions resulting from transport. The emissions due to transport to retailers should not be isolated but considered on a case to case basis in conjunction with the emissions from the production stage as part of a life cycle analysis.

International trade is also an essential factor for the resilience of food systems (Meridian Institute, 2011; Nelson *et al.*, 2010; HLPE, 2012a). As shown above, climate change is expected to have different effects in various regions of the world. This will increase the need for exchange of products. Trade can compensate for local production deficits caused by increased variability and extreme events. However, recent price volatility has shown that trade does not always buffer local production variations (HLPE, 2011; MacMahon *et al.*, 2011; FAO, 2012d). On the contrary, it can exacerbate and transmit the effects of a local shock, and consequently it can become a factor of systemic risk. In addition, price volatility has hit poor importing countries especially hard (HLPE 2011). Trade could then appear as a factor of risk, rather than a way to cope with shocks. Low and variable prices prevent investment in local production. Excessive reliance on imports to satisfy national needs can lead to severe food crisis during price upsurges, which are often aggravated by measures to restrict exports. Trade's role in improving the resilience of food systems would be enhanced paying greater attention to food security concerns (HLPE, 2011; 2012).

4. A DRIVER OF ECONOMIC DEVELOPMENT

The changes required in agricultural and food systems will require the creation of supporting institutions and enterprises to provide services and inputs to smallholders, fisherfolk and pastoralists, and transform and commercialize their production more efficiently. These changes will also require major investments from both public and private sector. For this reason, they will drive economic development and create jobs, especially in rural areas and in countries where agriculture is a major economic sector.

4.1 Development of services and input providers

Changes in the field require the introduction of new inputs, techniques and services. Making them accessible to small holders, pastoralists, fishermen and foresters, both physically and financially, is a major challenge. This situation in turn creates opportunities for the development of small local enterprises dedicated to providing inputs and services to farmers. For example, the implementation of the UDP technique in Bangladesh (see box 1) led to the creation of small enterprises that prepared briquettes from imported fertilizers. More generally, preparing and selling small bags of inputs, fertilizers or seeds, is often needed at the local level to make these inputs, which come from big enterprises, available and adapted to the needs of smallholders. This triggers the creation of small enterprises, often owned and operated by women.

Another good example is household metal silos. These silos have been actively promoted by FAO and various organisations to reduce post-harvest losses and enable farmers to store their grain on farm, instead of having to sell it just after harvest when prices are low. With proper storage facilities, households can use their harvest as collateral to access credit and sell it when prices are higher. Metal silo fabrication and marketing create jobs and develop rural enterprises. For example, in 2007 there were 892 metal silo manufacturers working in El Salvador, Guatemala, Honduras and Nicaragua. Some of these manufacturers are farmers complementing their income, others were jobless rural youth. The proximity of manufacturers to farmers enables them to respond immediately to farmers' needs. Studies show, that after an initial stage during which FAO, NGOs and development institutions play an essential role in disseminating the technique and training experts, the increased involvement of the private sector in silo production and farmer uptake is crucial for up-scaling the technology (Tefera *et al.*, 2011). In Afghanistan, two FAO silo projects were implemented. The 25 experts trained 65 tinsmiths and blacksmiths who in turn trained 300 national craftsmen, most of whom created their own business (Mejia, 2008). There is now a movement towards the construction of collective storage facilities, using the same technique, which provides the added benefit of gathering the harvest and facilitating its commercialization. Farmers in Uganda are building local storage facilities and have proposed the introduction of warehouse receipt systems (Akaki, 2012).

Conservation agriculture offers another good example of the development of service activities and input providers. Conservation agriculture requires specific equipment, be it hand tools, animal traction or tractor equipment, particularly for direct seeding and planting in non-tilled soil. This equipment is not readily available in many markets. As conservation agriculture becomes increasingly adopted, there is a greater market demand for the equipment, which is met at first by machinery dealers and then by the national manufacturing sector. In addition to this specific demand for new technologies, the higher profits of the farmers practicing conservation agriculture allow these farmers to invest into agricultural mechanization. These investments bring a number of off-farm income opportunities in the rural sector, including manufacturing, selling, servicing and repairing of machines and equipment. Such developments can be observed wherever agricultural mechanization has taken place (e.g. South Asia) but they can be seen specifically where conservation agriculture is being adopted. The longest term example is probably Brazil, which in the process of adopting conservation agriculture has developed a very competitive manufacturing sector for agricultural machinery (Casão Junior *et al.*, 2012). Similar developments can be noticed in many countries, where conservation agriculture is being adopted. In China, the demand for no-till equipment has created a fast growing manufacturing sector. Other examples can be found in India and Pakistan and more recently in Syria. In several African countries, no-till equipment manufacturing industries are developing, partly from established equipment manufacturers, partly from non-related workshops that have discovered that there is a new promising market for no-till equipment. Partly as a result of direct project work, including the training and promotion of local manufacturers and emergency interventions, the introduction of conservation agriculture technologies into new markets by using and strengthening existing equipment dealer structures or as a result of increased market demand, manufacturers and dealers for conservation agriculture equipment exist now, for example, in Kenya, the United Republic of Tanzania, Zambia, Zimbabwe and South Africa (Friedrich *et al.*, 2011; Owenya *et al.*, 2012, Marongwe, 2012). At this moment, the manufacturers are still mostly small and offer conservation agriculture equipment only as one line of their products. However, considering the history in more advanced countries like Brazil, it is expected that this sector of the industry will grow and will also bring more mechanization to the rural areas, in a more sustainable way than earlier attempts to promote agricultural mechanization. Such developments can, for example be seen in the United Republic of Tanzania, where conservation agriculture farmers start buying single axle tractors to replace the draft animals for a more timely completion of the field work. This fosters the development of the agricultural equipment sector, but also supports contractors offering mechanization services to farmers and of cover crop seeds. An important factor in the development of the agricultural equipment is South/South cooperation programmes, such as the one between Brazil and African countries (Mkomwa & Apina, 2008; IAPAR, 2008).

As shown in section 3, genetic resources are key both to sustainable intensification. These resources allow for a better use of other natural resources, such as land, water and nutrients and for better risk management. Often the best answer to a pest problem is the diffusion of a plant variety more resistant to it (Allara *et al.*, 2012). To provide seeds to smallholders requires not only conservation of genetic resources, but also plant breeders, seed producers, and proper retailing systems. All these activities constitute new opportunities to create local enterprises that are adapted to the needs of smallholders. Although business models and organization have to be adapted to local situations, studies show that these activities can provide added value for farmers, as well as new jobs (Van Mele *et al.*, 2011; FAO, 2010c).

BOX 7: BUILDING A SEED INDUSTRY IN AFGHANISTAN

Afghanistan national seed activities aimed at boosting agricultural productivity started in 1978 when key elements of a seed industry were put in place with donor funds. Unfortunately, the invasion in late 1979 and subsequent war which raged for over two decades, coupled with intermittent drought and pests problems, forced large number of people from rural communities to become Internally Displaced Persons (IDPs). The result was a dependence on imported food and seed through various forms of international assistance. From 1992 to 2004, FAO efforts to assist Afghanis to become self-sufficient in food production started with the in-country seed multiplication programmes with the Ministry of Agriculture. FAO took a comprehensive approach to the rehabilitation of the seed sector, which included participatory development of seed policy and regulations; capacity building for variety development and testing; early generation and certified seed production; and the rebuilding of the national seed service to provide quality control. Since 2004, FAO has expanded its efforts to focus on the establishment of local seed enterprises through training in business management, the provision of equipment and establishing a national seed association. As a strategy, FAO's sustained comprehensive approach linked the provision of quality seed of improved varieties for emergency distribution with long-term developmental seed projects, using the former as building block of the latter. For example in 1988, FAO procured from international sources 17 000 tonnes of improved seed with fertilizer as emergency seed relief to more than 500 000 farm families. In 2008, Afghanistan produced enough seed to meet the needs for emergency distribution. At the end of 2008, the following tonnage of seed for various crops used in Afghanistan were produced by farmers: wheat (12 000), maize (44), rice (812), potato (56), oil seeds (234), melon (2) and other vegetables (7). This has resulted in much higher rate in the use of certified seed in most of the region. To produce the certified seed the number of contract seed growers rose gradually from 125 in 2004 to 632 in 2008, while a total of 29 privately owned enterprises producing certified seed of international standards have been established and become functional. By 2011, it was expected that there would be 63 private seed enterprises producing cereal and vegetable seed. The net result of FAO intervention has led to a) yield improvement of staple crops (e.g. the wheat yield has increased from less than 2.0 tons per hectare to 3.7 tons through better management; b) the reduction of food insecurity as Afghanistan now produces most of the food consumed within the country; c) the improvement in income for rural people who are now involved in seed enterprises and chain cottage industries associated with them; d) critical mass of professionals being developed to take over farm management skills and agricultural production know-how; e) the use of available resources including human power; f) locally produced seed that have drastically replaced imported seed, leading to great savings in valuable foreign exchange earnings and; g) lower food prices for the non-farming population.

4.2 Transformation and access to markets

Changes in farming systems should be accompanied by changes all along food chains.

For instance, as pointed out by the HLPE (2012) increasing diversity in the field often requires changes in consumption patterns. In fact, diversification often requires changes all along food chains, from input production and distribution to collection, transformation and commercialization of the products. For these reasons, diversification is often more easily carried out as a collective project. Several diversified farms can realize the same economy of scale on each of their production systems as a specialized one. This can lead to the creation of services, for example to share machines and collect and sell their production.

The introduction of better processing techniques that are more resource efficient, not only reduces expenses but also often gives the opportunity to improve quality, exploit new markets and increase incomes. This in turn not only creates jobs in the agricultural and food sector, but also in other rural-based sectors.

BOX 8: FUELWOOD SAVING FISH PROCESSING TECHNOLOGY IN LIBERIA.

In small-scale fisheries of Liberia, poor processing methods often result in high wood consumption, increased production costs, poor quality product and lower prices. Over years, reduced availability of wood has made it harder to access. The wood either comes at a higher price or must be obtained by walking much further to gather it in the bush.

In Grand Cess, an important fishing centre on the south-west coast of Liberia in Grand Kru County, the proximity of the lucrative border market of Cote D'Ivoire provides an economic opportunity. However, operators wanting to sell to this market faced significant challenges to gaining greater benefits as they had to compete with better quality products from other fishing locations.

A Food Security for Commercialization for Agriculture (FSCA) project has worked since 2009 in the fishing centers of Grand Kru and Montserrado. For the economic empowerment of these communities, the FSCA project started its assistance by developing post-harvest fish technology platforms, including the construction of Chorkor fish smoking ovens and insulated containers for fresh fish storage. The Chorkor oven is well-known for its fuel efficiency (cutting by two-thirds the wood/fish ratio of traditional ovens), the reduced production of pollution (smoke) and its ability to generate good quality products. The Chorkor oven introduced by FSCA is now being widely used in Grand Kru as the best means of fish preservation. In total, 241 operators benefited from the project, out of which 179 were in Grand Kru. This technical intervention was combined with the development of organizational and entrepreneurial skills. The project has enabled the beneficiaries to access the cross-border market.

The Good Father Fishery Based Organization (GFFBO) is another good example. It is made up of 38 members, mainly women (27). With improved incomes from the sales operations and better management, the GFFBO initiated self-reliance actions. It did this by procuring a canoe, a 25 horsepower outboard engine and assortment of fishing gear. In addition, it also meet other variable costs of its members for one operational year. It then embarked on a plan to construct decent houses for members in line with their expressed objective of improved sustainable livelihoods. Based on training and practice sessions, and other outcomes during the project period, members are now anticipating opening their personal accounts with local banking institutions, as soon as banks are opened in Grand Kru. This example shows how a technical change can create an opportunity for triggering economic development, provided that the necessary assistance is put in place. It also shows how a change in one part of a system is rarely isolated, but can affect the whole system.

Source: Yahya *et al.* 2011

There are increasing social expectations and consumer demands for products of better quality, including taste, reduced environmental impact and higher symbolic value. Therefore, changes towards more sustainable production can also add value and create new market opportunities (FAO, 2012c).

The growing interest in local food systems in many developed countries, especially for fresh products, not only reduces energy consumption for conservation and transport, it also can add value for small farmers and lead to the creation of smaller, shorter food chains that are often collectively managed. This interest is also a sign of a renewed perception that the link between products and their place of origin gives these products certain appreciable qualities. This is key to the development of origin-linked products that are associated with a geographical indication that identifies them. Such approaches can give way to the creation of specific value chains, which can be a way attributing value to more diverse production (FAO, 2012c).

Voluntary sustainability standards, such as organic agriculture or fair trade can also play an important role, provided that their procedures are adapted to the needs of smallholders (FAO, 2012c).

BOX 9: FAO/UNEP PROGRAM ON SUSTAINABLE CONSUMPTION AND PRODUCTION (SCP) IN FOOD SYSTEMS

Sustainable consumption and production (SCP) has been on the international agenda since Agenda 21 (1992) identified unsustainable patterns of production and consumption as the major cause of the continued deterioration of the global environment. The 2002 Johannesburg Summit called for a ten-year framework of programmes in support of national and regional initiatives to accelerate the shift towards sustainable consumption and production.

FAO and United Nations Environment Programme (UNEP) have formed a joint Sustainable Food Systems Programme to improve resource use efficiency and reduce the pollution intensity of food systems from production to consumption, while at the same time addressing issues of food and nutrition security. The programme brings together a broad coalition of concerned stakeholders, including governments, food and fish producers, agro-industry, retailers and consumers.

The programme includes the following four 'clusters' of activities and outcomes:

1) Technologies which identify and adopt techniques, practices, policies and actions that increase sustainability/resource efficiency at every stage of food chains, and the enabling conditions and tools to promote them;

2) Monitoring tools, which involve the development of knowledge-based tools to assess and monitor sustainability of food systems, including life-cycle methodologies and data needs;

3) Promotion, which identifies ways and tools to recognize, give value to and promote sustainable production and products, including market-based mechanisms; and

4) Communication, which develops and implements tools to communicate information on sustainable consumption and production to actors along the supply chain including consumers and other interested stakeholders, with guidelines increase transparency and consistency.

The programme is being implemented through the Sustainable Food Systems Task Force on SCP. The Task Force, launched in 2010, is made up of 14 national governments, UN agencies and programmes, including FAO, UNEP, the United Nations Conference on Trade and Development (UNCTAD), the United Nations Department of Economic and Social Affairs (UN DESA) and the United Nations Industrial Development Organization (UNIDO), eight civil society organizations, and three international business organizations representing 325 firms. The role of the Task Force is to develop a coordinated approach to SCP and scale up specific activities, mobilize resources, share knowledge and foster partnerships.

4.3 Investing in a greening economy with CSA

As pointed out by the World Bank (2008), agriculture continues to be a fundamental instrument for sustainable development and poverty reduction. It contributes to development in many ways. In agriculture-based countries, it generates on average 29 percent of the gross domestic product (GDP) and employs 65 percent of the workforce. In transforming and urbanized countries, as distinguished by the World Bank in the World Development Report 2008, industries and services linked to agriculture often account for more than 30 percent of the GDP. Currently, 2.5 billion people live in households that are involved in agriculture. For these reasons, there can be no green economy without agriculture. CSA can be an important driver for a green economy, directly by increasing resource efficiency and resilience and indirectly by fostering the development of associated services and enterprises. The investments needed can also create new jobs and opportunities for the rural poor.

Since the end of 2008, the promotion of the concept of a green economy has been very much linked to the idea that investments should be focused on 'green' sectors. This was because these sectors, as opposed to 'brown' sectors, were seen as the sectors of the future that were going to provide more jobs. Climate change was a leading factor in drawing the line between 'green' investments - investments in sectors and activities that are good for the economy and good for the environment – (in this case, good for the climate) and 'brown' investments that were considered bad for the climate and not economically sustainable. The energy sector is the perfect example of a sector that offers very diverging choices.

One of the questions that emerged was "How was agriculture to position itself in this debate?" The issue is of considerable importance since the idea of a Global Green New Deal, launched by UNEP in March 2009, was to devote to green sectors an important part of the public subsidies aimed at addressing the financial crisis and its economic and social impacts. In this view, the links between agriculture, food security, economic growth and rural development, as UNEP (2009) pointed out, led to the identification of priority investments to be directed to agriculture, especially in agricultural productivity measures, freshwater management and sanitation, as these have demonstrable and exceptional social returns (UNEP, 2009).

The very often stressed (FAO, 2009c) need to invest in agriculture in developing countries is even greater when the need to address the challenges of climate change is included (FAO, 2010a; Nelson et al., 2009; Nelson et al.; 2010; HLPE, 2012). It must be emphasized that the major part of these investments will be made by the private sector, and most of them by the farmers themselves. Reducing risk and improving resilience is key to enabling private actors, especially the more financially vulnerable, to invest. Often these private actors will also need support, particularly during the transition phase towards new systems. Payments for environmental services can play an important role to facilitate this transition (Lipper and Neves, 2011).

The programme used by the Brazilian Agricultural Research Corporation (EMBRAPA) (2008) to make the projections presented in section 2.2 gives an excellent example of how climatic risks influence investments in agriculture. It was originally designed in 1996 to assess climatic risks for 30 different crops in more than 5 000 municipalities covering over 86 percent of the country's cultivated area. The programme is used as a tool to assist decision making in loan approval for agricultural investments. When the level of risk is considered too high the loan cannot be granted.

EMBRAPA has used it to assess potential levels of risk in the future.

There are in fact two approaches to consider investments in relation to risk. The first one is to integrate future risks, in which investments need to be designed to be resilient to future risks (FAO 2011d). The second approach is that investments can also help manage future risks and prevent or reduce damages. The reduction in damages should then be considered as a return on investment. Box 5 gives an example of how this could be assessed.

The 47 National Adaptation Programmes of Action (NAPA[6]) prepared by the least developed countries provide a rich panorama of adaptation priority measures. These projects are of special interest and relevance because they have been designed and prioritized by the countries themselves. The preparation process sought to identify key adaptation needs by analysing potential effects of climate change on each sector, assessing vulnerabilities and developing a list of adaptation activities and projects, including multistakeholder consutations (UNFCCC 2002). The ranking of priority areas was done through identification of the most urgent needs, taking into account the vulnerability of sectors, vulnerability of groups, the contribution of projects to food security and to poverty reduction, and their cost. They are the priority projects of the most vulnerable countries and reflect their urgent needs. They also give an idea of future needs in less vulnerable countries.

Projects are classified according to 'sectors' which were defined by the UNFCCC. According to this categorization, food security is the first sector with 20 percent of the projects, followed by terrestrial ecosystems (16 percent) and water (15 percent). A closer analysis of all the categories (Meybeck *et al.*; 2012) shows that most of these priority projects are linked to agriculture, including forestry and fisheries.

Cross-sectoral projects include meteorological and hydrological information (forecasting, early warning), and community-based management and integrated management, especially of land. Early warning systems and disaster management include weather forecasting systems; early warning systems on climate, drought, floods, natural disasters, and food security; and, less often, disaster management preparedness, strategy and response capacity. Education and capacity building are especially aimed at local authorities, including for planning and zoning and at vulnerable communities, households and farmers.

The projects for coastal zones and marine ecosystems include restoration and integrated management of coastal areas, and measures aimed at mangroves, coral reefs and dunes. For terrestrial ecosystems, projects include watershed management and restoration; landslide and flood prevention; restoration and management of wetlands and lakes; erosion control; soil conservation; and restoration of degraded land. The majority of the projects on water resources are linked to irrigation, such as water management and efficiency; improvement of irrigation systems, dams and reservoirs; rain water harvesting; better management of ground water (including wells); and

6 http://unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php

better hydrological management (including prevention of floods). Some of the projects are concerned with water quality and drinking water supply, especially in Small Island States (SIDS). The majority of the projects on infrastructure are concerned with water (irrigation, dams, canals).

With respect to plant production, the food security category includes projects on irrigation and supplemental irrigation; soil conservation; research on and access to drought, flood and salinity tolerant crops; short-cycle crops; multiplication of improved seeds; and adaptation to salinity. For livestock, the projects cover issues related to pastoral area management; livestock mobility; fodder crop species in pastoral areas; fodder production and stocks; and genetic improvement of local breeds. Also included in the food security category are projects to improve fisheries management and increase fish production. This category also includes projects for diversification; integration of crop and livestock systems; intensification of production; increasing the value added through processing, marketing and promotion of secondary professions; and income generating activities.

The energy category includes projects for energy efficiency, the development of renewable energy to protect forests and the development of renewable energies as a way of diversifying production. The two projects in the insurance category both include agriculture. Even in the health category, the projects for prevention of water-borne diseases, especially for monitoring and control of vector diseases and diseases related to the risks associated with climate change, have close links with agriculture.

These projects are of particular relevance for a green economy. Not only do they increase resilience, and, as is most often the case, the efficiency of agricultural systems, most of them will immediately create jobs in order to be implemented. These projects will also, over the long term, generate returns in avoided damages. Also, as they reduce risks, they also facilitate private investment.

Among the needed investments figure important land management schemes and infrastructure, such as local roads and irrigation systems, which are an important source of job creation in rural areas. These public works can be supported by social protection schemes in order to provide work, food and income to food-insecure people. A recent report of the HLPE (2012b) reviews some of these schemes and concludes that public works programmes have proved to be efficient in dealing with covariate shocks and, if they are well designed, can contribute to improving food security.

Major investments are also needed in research (HLPE, 2012a; Beddington *et al.*, 2012c). To be able to embrace the whole range of issues to be addressed, these investments need to be coordinated at a global scale. Increased investment in public research is particularly needed in areas where return on investment cannot immediately benefit the private sector. To address systemic issues to be adapted to local specificities and needs, research will have to be closely linked to extension services and be open to local knowledge and to the demands addressed by all stakeholders, including small-scale food producers (HLPE, 2012). The transfer of technology will also play an important role. It should include the development of the human capacity to accommodate the technology and structured partnerships to ensure that it is adapted and established locally.

5. CONCLUSION GREENING THE ECONOMY WITH CSA: OPERATIONALIZING SUSTAINABLE DEVELOPMENT

Twenty years after Rio, we can well ask ourselves "What's different?" And indeed, what is different about CSA? (Grainger-Jones, 2011).

The green economy and CSA share the common goal of integrating the three dimensions of sustainable development. Both make sustainable development concrete by focusing on issues that can and must be addressed right now in local communities but that have global, long-term consequences.

CSA brings together global and local concerns, climate change to be addressed, global impact of agriculture, climate change to get adapted to, local impact of a global change; and first of all, food security, both local and global. To do so it brings together practices, policies and institutions which are not necessarily new. What is new is to bring together practices and policies in order to address multiple challenges, faced by agriculture and food systems, now and for the future. What is new is to avoid having contradictory policies by internally managing the trade-offs and synergies in the pursuit of multiple objectives.

As pointed out by the HLPE (2012), "addressing food security and climate change requires concerted and coordinated involvement and action of many actors, farmers, private sector, and public actors national and international, civil society and NGOs. It is especially challenging as they are very different, sometimes have conflicting objectives and there is a need to work on a long term perspective while most of them have to consider first a short term outcome. This requires the involvement of all stakeholders."

Integrating food security and climate change concerns has to be done at every level and pursued at different scales. It needs to be done on a day-to-day basis at farm level. But it also must be carried out with a long-term perspective at the landscape level and country level to design locally specific, coherent, inclusive and cohesive policy packages.

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