منظمة
الأغذية والزراعة
للأمم المتحدة

联 合 国
粮 食 及
农 业 组 织

Food and Agriculture
Organization of the
United Nations

Organisation des
Nations Unies pour
l'alimentation et
l'agriculture

Продовольственная и
сельскохозяйственная
организация
Объединенных Наций

Organización de las
Naciones Unidas para la
Alimentación y la
Agricultura

Viale delle Terme di Caracalla, 00153 Rome, Italy **www.fao.org**
Our Ref.: D **Your Ref.:** FCCC/SBSTA/2014/L.14

Submission by the Food and Agriculture Organization of the United Nations (FAO) to The United Nations Framework Convention on Climate Change (UNFCCC) on Issues relating to agriculture: agricultural practices and technologies

Submission D: Identification and assessment of agricultural practices and technologies to enhance productivity in a sustainable manner, food security and resilience, considering the differences in agroecological zones and farming systems, such as different grassland and cropland practices and systems[1] as requested in the conclusions of SBSTA 40 (FCCC/SBSTA/2014/L.14, Item 8, Paragraphs 3 (d) and 5).

Summary of the submission

Eradication of hunger, malnutrition and poverty, improving agricultural productivity as well as sustainable management of natural resources are central to FAO's mission and are outlined in the UN Sustainable Development Goals (SDGs).

According to FAO, food production will need to increase by 60 percent to satisfy an increasing demand driven by population growth and changing diet patterns. At the same time, natural resources such as land, soil and water are getting scarcer, and are subjected to competing demands, including for bioenergy production. As a result there is a global need to make more efficient use of these resources. For example small holders and family farmers, fishers, foresters and herders are very dependent on these resources, as are countries and areas experiencing specific scarcity. Not only the global availability of food but also the incomes and livelihoods of the most vulnerable depend on increased productivity. All dimensions of Food security and nutrition within diverse contexts need to be better understood. The different productivity factors, as well as social and economic dimensions, include, among other things, labour, gender and cost. Better use of resources and more efficient and productive systems are the main way to reduce greenhouse gas emissions in the agriculture sectors as these are generally correlated with input use. However, there can be trade-offs between greater efficiency and resilience in certain situations.

A holistic approach must be taken when looking at the challenges that agricultural systems have to address simultaneously in order to ensure food security through improved productivity and resilience. Such an approach will address multiple needs and objectives considering the four dimensions of food security and nutrition (availability, access, use and utilization, and stability). This approach will enhance the effectiveness of actions undertaken to manage climate change and to address simultaneously the linked challenges of food security and climate change. For such a holistic approach to be mainstreamed, it will be essential (i) for farmers, fishers, foresters, herders and other rural people to see tangible advantages in terms of higher incomes, reduced costs or labour and sustainable livelihoods; and (ii) policy-makers to design and implement supportive policy frameworks that include incentives, address climate change issues and rural development, and foster synergies between multiple benefits through the sustainable transformation of agriculture.

The identification of agricultural practices and technologies to enhance food security, resilience and productivity in a sustainable manner, show the need to adequately identify and valorize synergies between productivity and resilience, and to identify and manage potential trade-offs. Particularly in the agricultural sectors, there are many synergies and interactions between what is generally considered under mitigation and what is generally considered under adaptation. Environmental, economic and social co-benefits are also important as they are often what trigger action on the ground. However, the work streams and mechanisms established so far under the UNFCCC have not always enabled such considerations. From FAO's perspective, enabling this has been one of the great accomplishments in the series of SBSTA workshops. It is important to find ways to develop such approaches to enhance synergies and co-benefits through the instruments established under the Convention.

---

[1] See Annex 1 for the definitions and scope considered in this submission.

FAO welcomes the opportunity to provide its views on such an important topic in line with its three main goals[2] and its support to countries in relation to "the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to adverse impacts of climate change" as recognized in The Paris Agreement preamble (Annex of the FCCC/CP/2015/L.9). Ensuring food security is a global priority and remains a key priority in most economies, in particular in developing countries. This submission is also guided by the Sustainable Development Goals (SDGs) and by the key role of the agriculture sectors. They are at the heart of most of the 17 SDGs, beginning with SDG-1, "No Poverty", SDG-2 "Zero Hunger" and SDG-6 "Clean Water and Sanitation". Food security, and its linkages with natural resources and rural development, features in most of the SDGs. Actions to address climate change are explicitly addressed in SDG-13, specifically devoted to combating climate change and its impact, but also in SDG-15, "Life on Land". Notwithstanding this, climate change is a driver that could potentially impact the whole 2030 Agenda.

1. Climate change and the food security challenge

Reducing hunger remains an important challenge as almost 795 million people still remain chronically undernourished, one fifth of whom are stunted children under the age of five. There is a strong correlation between the chronically undernourished and the 836 million people living in extreme poverty, who are often small-holders living in rural areas (FAO, 2016a). Moreover, women and girls are overrepresented among those who are food-insecure, and there is another strong correlation between hunger and gender inequality (ADB, 2013). Furthermore, FAO estimates that population growth and dietary changes will drive growing food demand, and production will have to increase by 60 percent by the middle of this century (Alexandratos & Bruinsma, 2012), unless diets evolve towards more sustainable consumption patterns.

Most production systems in all agricultural sectors (comprising crops, livestock and grasslands, forestry, fisheries and aquaculture) will be impacted, both directly and indirectly, by climate change. Climate change will result in changing temperatures and precipitation patterns – both key drivers of production. The weather variability and extreme events such as drought, floods, and heatwaves will negatively affect all agricultural sectors. Ocean acidification in aquatic systems is a direct consequence of the increase in CO_2 in the atmosphere and is already affecting fisheries and aquaculture. Furthermore, soil and water, which are essential for all types of agriculture, and are also fundamental to other aspects of human societies, have already been strongly impacted and degraded[3]. The genetic resources needed for production and adaptation are also being threatened by climate change. Climate change risks disrupting ecosystem structure and functionality. Further loss or degradation of those resources will negatively impact food prices in the long term and increase the risk of hunger for millions. As a result, both short-term climate variability and long-term continuous climate change will increase risks to the four dimensions of food security and nutrition.

The identification and implementation of agricultural practices and technologies that enhance productivity in a sustainable manner, could contribute to better management of natural resources, including genetic resources which are essential for coping with climate change (FAO, 2015), and thus reduce the impacts of climate change. Those practices should ideally equally contribute to adaptation and mitigation practices.

Therefore, a holistic approach covering all agricultural sectors (comprising crops, livestock and grasslands, forestry, fisheries and aquaculture) and their correlation with food security and other human needs, would improve the effectiveness of actions undertaken to manage climate change by intrinsically addressing the linked challenges as one.

---

[2] FAO's three main goals are: the eradication of hunger, food insecurity and malnutrition; the elimination of poverty and the driving forward of economic and social progress for all; and, the sustainable management and utilization of natural resources, including land, water, air, climate and genetic resources for the benefit of present and future generations.

[3] See on soil degradation the first Status of the World's Soil Resources published by the Intergovernmental Technical Panel on Soils (ITPS) of the Global Soil Partnership (FAO and ITPS, 2015a).

2. Agricultural practices and technologies to enhance sustainable productivity, increase resilience and food security for different agroecological zones and farming systems

Addressing climate change, eradicating hunger and poverty and enhancing the sustainable management of natural resources in the agricultural sectors is at the heart of the SDGs. According to FAO, food production will need to increase by 60 percent to satisfy an increasing demand driven by population growth and changing diet patterns. At the same time, natural resources such as land, soil and water, are getting scarcer, and are submitted to competing demands, including for bioenergy production. There is thus a global need to better use these resources. For example small holders and family farmers, fishers, foresters and herders are dependent on these resources, as are countries and areas experiencing specific scarcity. Not only the global availability of food but also the income and livelihoods of the most vulnerable depend on increased productivity. All dimensions of food security and nutrition within diverse contexts and productivity need to be understood. This includes different productivity factors, as well as the social and economic dimensions including labour, gender and cost. Better use of resources and more efficient and productive systems are the main way to reduce greenhouse gas emissions in the agriculture sectors as these are generally correlated to input use. However, there can be trade-offs between greater efficiency and resilience in certain situations.

The agricultural practices and technologies that enhance sustainable productivity, increase resilience and food security can often be found as part of traditional and indigenous knowledge, and have also been consolidated by FAO and other actors through years of experience and consultation on sustainable agricultural development at research, development and policy levels, covering all agricultural systems.

The practices have been widely documented and concern all sustainable land management categories. For instance, an exhaustive review of the agricultural practices and technologies that enhance sustainable productivity, increase resilience and food security for different systems has been published by FAO (FAO, 2013a). It covers all aspects in terms of water, soil, energy, and genetic resources. Furthermore, it concerns all production systems including crop production systems, livestock, forestry, fisheries and aquaculture, and also improved post-harvest management and food chains (FAO, 2013a). The practices include those detailed by the IPCC across its successive Assessment Reports addressing GHG emissions (IPCC, 2014a) and adaptation and vulnerability (IPCC, 2014b, c).

Practices that have the potential to enhance sustainable productivity, increase resilience and food security in crop production can be organized around five main themes: (i) maintaining healthy soil to enhance soil-related ecosystem services and crop nutrition, including through integrated nutrient management; (ii) cultivating a wider range of species and varieties in associations, rotations and sequences; (iii) using quality seeds and planting materials of well adapted, high-yielding varieties; (iv) adopting integrated pest management to reduce impacts of pests, diseases and weeds; and (v) managing water efficiently, including soil moisture and, the case being, irrigation practices.

For livestock, the main strategies range from intensification at field level through to increased productivity of grassland production (e.g. though fertilization, association with nitrogen-fixing herbs or trees, pasture and grass cutting regimes), herd management and animal breeding to select more productive and resilient animals (for instance, making use of locally adapted breeds, which are not only tolerant to heat and poor nutrition, but also to parasites and diseases) and overall actions targeting the health of the animal which includes better veterinary services, preventive health programmes and improved water quality.

In the forest sector, sustainable forest management (SFM) is the internationally recognized approach to forest policy planning and management tailored to each country's particular conditions and designed to achieve economically, environmentally and socially balanced benefits from forests (FAO, 2011c). As such, SFM is the foundation for sound forest sector management, whether the aim is to enhance productivity, food security, resilience or to achieve another goal, e.g. SDGs and climate change issues (FAO 2013b). Some key strategies for increasing productivity include restoration of degraded forests and landscapes, increased area of planted forests and agroforestry systems, and more intensive forest management. Increasing forest resilience may be achieved through a range of practices including adjusting forest management practices to reduce exposure and risk; promoting species and varieties that are less vulnerable to gradual climate change and extreme events; increasing forest and vegetation cover on areas at greater risk of erosion; and intensified pest, disease and wildfire management. Promoting agroforestry systems, supporting community-based forest enterprises, creating more forest employment, and securing rights for access and use of forest foods and other products are some of the means by which the forest sector can contribute to enhanced resilience and food security.

In the fisheries and aquaculture sector, options to increase productivity, food security and resilience include, for example, reducing fishing overcapacity and the race to fish through improved fisheries management, reducing discards and waste through by-catch reduction technologies and improved use of catches, integrated and multi-trophic aquaculture systems and improved fish conversion ratios in aquaculture feed, and reduced losses and increased energy efficiency in the post-production supply chains. These are efforts will decrease input use, increase a broad range of ecosystem services from aquatic habitats such as mangroves and peatlands, increase food security through maximizing biological and economic yields[4] and improve the general resilience of the linked social-ecological systems.

Integrated crop, livestock, fish and agroforestry production systems offer a wide range of opportunities. Those systems improve the economic and ecological sustainability of agricultural systems and at the same time provide a flow of valued ecosystem services. Through increased biological diversity, efficient nutrient recycling, improved soil health and forest conservation, integrated systems increase environmental resilience and contribute to both climate change adaptation and mitigation. They also enhance livelihood diversification and efficiency by optimizing production inputs, including labour. In this way, integrated systems also increase producers' resilience to economic stresses.

It will also be important to build greater resilience to production systems – improving their capacity to continue functioning and producing in the face of changes and shocks. Diverse genetic resources can play a significant important role in this. As mentioned above, it refers to the importance of making use of the rich diversity of crops, livestock trees and fish. But it concerns also the presence of several different pollinators or biological control agents. Indeed, they tend to promote stability in agricultural systems because some species may be able to cope with shocks or changes that severely affect others. Therefore, all management practices that will favor increased diversity, including genetic diversity within species, are important for these very reasons. Furthermore all practices, technologies and early warning systems that improve the health and conditions of the different production systems, eventually enhance productivity as a whole and thus also increase the sustainability of production and its resilience.

Besides the production systems themselves, the whole food supply chain should be considered. Global quantitative food losses and waste per year are, at global level, roughly 30 percent for cereals, 40–50 percent for root crops, fruits and vegetables, one-fifth for oil seeds, meat and dairy plus 35 percent for fish (FAO, 2011a) Food losses during harvest and in storage translate into lost income for small producers and into higher prices for poor consumers. In developing countries food waste and losses occur mainly in the early stages of the food value chain. Strengthening the overall supply chain through the direct support of producers and post-harvest systems and investments in infrastructure, transportation, as well as in an expansion of the food and packaging industry could help to reduce the amount of food loss and waste, and therefore increase the overall productivity of agricultural systems and all dimensions of food security.

Efficiency and resilience should be twin-goals together and on various scales in the different agricultural systems and components of food chains. Being efficient without being resilient will not be helpful over the long term, given that shocks will occur more often due to climate change. 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 might be more sensitive to heat waves. On the other hand, increased efficiency can be a factor in increasing resilience. Increasing production in food importing countries will

---

[4] One study estimated the economic losses due to overfishing/fuel use, pollution and habitat loss are estimated to exceed $50 billion (Willmann and Kelleher, 2009) and an up-coming revision of the analysis puts that estimate at $87 billion. http://documents.worldbank.org/curated/en/2009/01/10298304/sunken-billions-economic-justification-fisheries-reform

improve their resilience to price volatility. Increasing soil carbon stocks or enhancing diversity in the field is of particular interest with regard to improving efficiency and resilience of food systems. Increasing soil organic carbon improves both efficiency and resilience. It improves nutrient and water intake by plants, which increases the yields and resource efficiency of land, nutrients and water. It also reduces soil erosion and increases water retention (FAO and ITPS, 2015a, b, UNCCD-SPI, 2015).

Finally, the increased variability of climatic conditions reinforces the need for a much broader vision of risk management and consequently an approach that benefits from a diversity of responses versus the use of single one-size-fits-all solutions. **Using a broad range of crop varieties, livestock breeds, forest trees and aquatic organisms that can survive and produce in different climates, and represent key components of resilience and adaptability of agriculture, will be essential in future production systems**. Making use of such diversity will guarantee broader protection from unexpected climatic events than the use of a single "more adapted" variety (FAO, 2015).

Governments widely acknowledge that adaptation is a vital part of the response to climate change. In addition, it is important to recognize that, even with the ongoing and intended activities to combat the climate challenge, GHG emissions will need to be reduced in all sectors. If this does not happen, measures for adaptation or disaster risks reduction will be insufficient to safeguard the wellbeing of vulnerable populations. Moreover, the cost of adaptation will increase if land, biomass and water systems lose their capacity to reduce and remove emissions. Fortunately, most adaptation actions within the agriculture sectors also provide large potential for efficiency gains, thus contributing to climate change mitigation, in addition to the substantive carbon sequestration potential offered by soils, coastal systems and forests.

All those practices have different productivity, adaptation and mitigation outcomes for the different agro-ecological zones and production systems as detailed in reviews and case studies published by FAO (e.g. FAO, 2011b and FAO, 2016b). Annex 2 of this submission showcases some concrete examples from diverse agro-ecosystems and socio-economic contexts, including questions of gender, and biophysical factors. Moreover, FAO, through several programmes (e.g. Blue Growth Initiative[5], CSA[6], EPIC[7], Energy related programmes[8], FAO-Adapt programmes[9], LEAP[10], MICCA[11], Framework programme on Resilience and Disaster Risk Reduction[12], and UN-REDD[13]) is proposing some useful tools (e.g. EX-ACT[14], GLEAM[15], MOSAICC[16], SFM Toolbox[17], WEF nexus tool[18]) to help identify and assess the best options adapted to each context, as detailed in the case studies (Annex 2). FAO also developed learning material to assist several stakeholders to better understanding identification and assessment of the options, including an E-learning tool on community based adaptation[19] addressed at agricultural extension staff, community based organizations and field.

3. Synergies, co-benefits and trade-offs

For a number of years FAO has worked with the overall aim to enhance food security, resilience and productivity in a sustainable manner in the agricultural sectors. FAO works on identifying, assessing and

---

[5] Blue Growth Initiative (BGI), http://www.fao.org/zhc/detail-events/en/c/233765/

[6] Climate-Smart Agriculture, forestry and fisheries (CSA), http://www.fao.org/climatechange/climatesmart/en/

[7] Economics and Policy Innovations for Climate-Smart Agriculture (EPIC), http://www.fao.org/climatechange/epic/home/en/

[8] http://www.fao.org/energy/en/

[9] Framework programme on climate change adaptation, http://www.fao.org/climatechange/fao-adapt/en/

[10] Livestock Environmental Assessment and Performance (LEAP), http://www.fao.org/partnerships/leap/en/

[11] Mitigation of Climate Change in Agriculture (MICCA), http://www.fao.org/in-action/micca/en/

[12] See http://www.fao.org/resilience/background/en/ and https://www.unisdr.org/partners/united-nations/fao

[13] United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD), http://www.un-redd.org/

[14] EX-Ante Carbon balance Tool (EX-ACT), http://www.fao.org/tc/exact/ex-act-home/en/

[15] Global Livestock Environmental Assessment Model (GLEAM), http://www.fao.org/gleam/en/

[16] MOdelling System for Agricultural Impacts of Climate Change (MOSAICC), www.fao.org/climatechange/mosaicc/

[17] Sustainable Forest Management (SFM) Toolbox, www.fao.org/sustainable-forest-management/toolbox/sfm-home/

[18] Water-Energy-Food (WEF) Nexus Rapid Appraisal, www.fao.org/energy/88425/

[19] www.fao.org/climatechange/67624/

promoting the agricultural practices and technologies that can help meet these objectives, and develop them to capitalize on the synergies between adaptation and mitigation.

Climate-smart agriculture, forestry and fisheries (CSA), as defined and presented by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, focuses explicitly on productivity and climate aspects. This approach pursues the triple objectives of improving food security by sustainably increasing productivity and incomes, adapting to climate change and reducing GHG emissions and enhancing removals where possible. This does not imply that every practice applied in every location should produce "triple wins". CSA seeks to identify and reduce trade-offs and promote synergies by taking these objectives into consideration to inform decisions on all scales and in the over short and long-term, to derive nationally and locally-acceptable solutions; all in line with the national development goals. CSA takes into consideration the diversity of social, economic, and environmental contexts, including agroecological zones and farming systems, where it will be applied. In 2015, over 30 Parties to the UNFCCC have included CSA in their Intended Nationally Determined Contributions (INDCs), which now form the basis of action to be taken under the Paris Agreement (FAO, 2016c).

The "Save and Grow" approach (FAO, 2011d) is also fully consistent with the principles of CSA. It promotes specifically sustainable crop production intensification, which produces more from the same area of land while conserving resources, using the appropriate genetic resources, reducing negative impacts on the environment and preserving natural capital and their associated provisions of ecosystem services. Recent documentation showcases successful smallholder adoption and implementation of the Save and Grow paradigm for the world's three major staple crops – maize, rice and wheat (FAO, 2016b). But other productions, such as pulses which are highly nutritious, also offer options for sustainable agriculture and contribute to climate change mitigation and adaptation[20]

The questions of scale must be duly considered when enhancing productivity and food security while capitalizing on the synergies. Here opportunities for emission intensity reductions must be taken into account. For example, while agronomic intensification to increase crop production at the field or plot scale may increase emissions locally; at a regional level, it is likely to result in increased production in areas capable of high productivity while reducing conversion pressure on other land, avoiding, for instance, forest or savannah degradation and biodiversity losses that would be associated with land conversion. Therefore, enhancing productivity might reduce the need for additional agricultural land and consequently avoid overall emissions.

Coastal and terrestrial agro-ecosystems, through photosynthesis, are the only productive systems that have the capacity to remove GHGs from the atmosphere cost-effectively and without potential risks associated with GHG accumulation. At the same time, agricultural systems that sequester carbon can increase their productivity, health and resilience while contributing to food security. Furthermore, the emissions and sinks from the different managed and unmanaged ecosystems are in most cases interdependent.

Trade-offs should also be addressed, in particular when managing biomass residues and their possible competing uses between soil quality, animal feed and bioenergy. In particular, smallholder farmers and fishers can face adoption barriers, such as access to capital, labour needs, tenure security, knowledge and technical support and this should be addressed.

4. Conclusions and recommendations

Ultimately, agricultural practices and technologies that enhance sustainable productivity, increase resilience and food security and address climate change issues in different agroecological zones, farming, fishery and forest systems are all based on the objective to increase efficiency in the use of energy, water, soils and other natural resources. These practices and resources also increase the resilience of the system through the sustainable management of the "living" part of natural resources such as ecosystems, species, and genetic resources. This allows for improved energy and resource use efficiency and supports the natural system's ability to absorb and store carbon. Nevertheless, such a general, holistic approach must then be tailored to each site-specific ecological and socio-economic condition. Moreover, for such a holistic approach to be

---

[20] www.fao.org/pulses-2016/

widely adopted, it will be essential (i) for farmers, fishers, foresters, herders and other rural people to see tangible advantages in terms of higher incomes, reduced costs or labour and sustainable livelihoods; and (ii) policy-makers to design and implement supportive policy frameworks. Such frameworks include incentives; they address climate change issues and rural development; foster synergies between sectors; and capture multiple benefits through sustainable management in and transformation of the agricultural sectors as well as sustainable land management at the landscape level.

The identification of agricultural practices and technologies to enhance productivity, food security and resilience in a sustainable manner, show the need to adequately identify and valorize synergies between productivity and resilience as well as to identify and manage potential trade-offs. In the agricultural sectors in particular, there are interactions between what is generally considered under mitigation and what is generally considered under adaptation. Co-benefits are also important, environmental, economic and social, particularly because they are often what triggers action on the ground. However, the work streams and mechanisms established so far under UNFCCC do not often enable such consideration. From FAO's perspective, enabling this has been one of the great accomplishments in this series of SBSTA workshops. It is important to find ways to develop such approaches to valorize synergies and co-benefits in the instruments established under the Convention.

References

Alexandratos, N. and J. Bruinsma. 2012. *World agriculture towards 2030/2050: the 2012 revision.* ESA Working paper No. 12-03. Rome, FAO. Available online at http://www.fao.org/docrep/016/ap106e/ap106e.pdf

Asian Development Bank (ADB) 2013. Gender equality and food security—women's empowerment as a tool against hunger. Mandaluyong City, Philippines: Asian Development Bank, 2013. Available online at www.fao.org/wairdocs/ar259e/ar259e.pdf

Food and Agriculture Organization of the United Nations (FAO). 2011a. Global food losses and food waste: Extent, causes and prevention. FAO, Rome. Available online at http://www.fao.org/docrep/014/mb060e/mb060e00.pdf

Food and Agriculture Organization of the United Nations (FAO). 2011b. Climate-Smart Agriculture: A synthesis of empirical evidence of food security and mitigation benefits from improved cropland management. FAO, Rome. Available online at http://www.fao.org/docrep/015/i2574e/i2574e00.pdf

Food and Agriculture Organization of the United Nations (FAO). 2011c. Climate change for forest policy-makers. An approach for integrating climate change into national forest programmes in support of sustainable forest management. FAO, Rome. Available online at http://www.fao.org/docrep/015/i2429e/i2429e00.pdf

Food and Agriculture Organization of the United Nations (FAO). 2011d. Save and Grow. A policymaker's guide to the sustainable intensification of smallholder crop production. FAO, Rome. Available online at http://www.fao.org/3/a-i2215e/index.html

Food and Agriculture Organization of the United Nations (FAO). 2013a. Climate-smart agriculture source book. FAO, Rome. Available online at http://www.fao.org/docrep/018/i3325e/i3325e.pdf

Food and Agriculture Organization of the United Nations (FAO). 2013b. Climate change guidelines for forest managers. FAO, Rome. Available online at http://www.fao.org/3/i3383e.pdf

Food and Agriculture Organization of the United Nations (FAO). 2015. Coping with climate change – the roles of genetic resources for food and agriculture. Rome. Available online at http://www.fao.org/3/a-i3866e.pdf

Food and Agriculture Organization of the United Nations (FAO). 2016a. Climate Change and Food Security: Risks and Responses. FAO, Rome. Available online at http://www.fao.org/3/a-i5188e.pdf

Food and Agriculture Organization of the United Nations (FAO). 2016b. Save and Grow in practice: maize, rice, wheat. A guide to sustainable cereal production. Available online at http://www.fao.org/3/a-i4009e.pdf

Food and Agriculture Organization of the United Nations (FAO). 2016c. Agriculture sectors in the INDCs - An Analysis of submissions. Forthcoming in 2016.

Food and Agriculture Organization of the United Nations (FAO) and Intergovernmental Technical Panel on Soils (ITPS). 2015a. Status of the World's Soil Resources (SWSR) – Main Report. FAO, Rome. Available online at http://www.fao.org/3/a-i5199e.pdf

Food and Agriculture Organization of the United Nations (FAO) and Intergovernmental Technical Panel on Soils (ITPS). 2015b. Can carbon (SOC) offset the Climate change? FAO, Rome. Available online at http://www.fao.org/fileadmin/user_upload/GSP/docs/soc/carbonSOC2.pdf

Intergovernmental Panel on Climate Change (IPCC). 2014a. IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the IPCC. Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2014b. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the IPCC. Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2014c. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the IPCC. Cambridge University Press.

Science-Policy Interface of the United Nations Convention to Combat Desertification (SPI-UNCCD). 2015. Pivotal soil carbon. Science-Policy Brief n°1, November 2015, Bonn, Germany. Available online at http://www.unccd.int/Lists/SiteDocumentLibrary/Publications/2015_PolicyBrief_SPI_ENG.pdf

Willmann R., Kelleher K. 2009. The sunken billions: the economic justification for fisheries reform. Agriculture and rural development. Washington, DC, World Bank. Available online at http://documents.worldbank.org/curated/en/2009/01/10298304/sunken-billions-economic-justification-fisheries-reform

Annex 1: Definitions and scope

For the purpose of this submission, FAO utilizes the following definitions and scope in the terminology used

- Agriculture’’ and agricultural sectors’’ includes crops, livestock and grasslands, forestry, fisheries and aquaculture;
- “Productivity” refers to the rate of production or rate of energy flow and commonly expressed in quantity of matter/biomass produced by day and unit of surface or production unit, efficiency refers to the efficiency of production systems in the use of resources and in the context of climate change, related to the impact on the GHG emissions and sinks;
- Practices and technologies:

FAO considers practices and technologies in their broad sense; they include all activities, from indigenous knowledge use to produce food, fibre, construction material and bioenergy. Technologies consist of practices or techniques, tools, equipment, know-how and skills, or combinations of the aforementioned elements.

Technologies include the Convention on Biological Diversity’s (CBD) definition of ‘biotechnology’: "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use". For more information: http://teca.fao.org/technologies

- ‘Agro-ecological zones’, as defined by FAO and its partners as the standardized framework for the characterization of climate, soil and terrain conditions relevant to agricultural production www.fao.org/nr/gaez/
- Farming systems: The classification of the farming systems in developing regions can be based e.g. on the following criteria www.fao.org/farmingsystems/description_en.htm

Annex 2: Case studies of agricultural practices and technologies addressing the issues of the submission

The following case studies present different sustainable ways to ensure enhanced food security, productivity and resilience within different farming systems in various agroecological zones:

These cases highlight some concrete examples of applying a holistic approach to diverse agro-ecosystems and socio-economic contexts, including questions of gender, and biophysical factors.

Case 1: Higher rice yields from healthy plants in healthy soil – ensuring productive crop production through System of Rice Intensification

Location: Tropical monsoon, irrigated and upland rice systems e.g. in South-East Asia

Agricultural practice: Crop production: System of Rice Intensification (SRI)

Food and nutrition security: Improved; reduced fresh water pollution

Productivity: Improved: yields increased +10%;

Resilience: Water-use reduced by 25–47% (India & China)

Mitigation co-benefit: at least 1/6 of greenhouse gas (GHG) emission reductions (CH_4) and reduced need of nitrogen fertilizers

The System of Rice Intensification (SRI) is a set of crop, soil and water management practices. Since 1980s SRI has been used by millions of farmers with benefits in terms of yield, efficiency and reduced cost and negative impacts. The system is based on growing rice in most, aerated soil. Rice seedlings are transplanted singly with regular spacing between plants. The soil is irrigated only intermittently followed by dry periods of three to six days. Weeding is done at regular intervals, and compost, farmyard manure and green manure are preferred to mineral fertilizer. The healthy soils give rice plants better access to nutrients.

System helps to overcome many challenges of the rice sector

SRI reduces the use of water, seed, fertilizer and pesticide. In some regions the system has increased the demand for labour, but technological innovations have helped to reduce the costs. The innovations include seedling trays, and zero-tilled, furrow-irrigated, permanent raised beds under organic mulch.

Apart from the increase in rice yields by more than ten percent. The water consumption has also reduced e.g. in India and China by 25 to 47 percent compared to flooded systems. In Nepal, farmers report that they need 10 to 20 percent less seed compared to traditional systems. Vietnamese farmers have increased their per hectare net incomes by almost US$ 200 using SRI practices.

In terms of climate benefits, SRI may allow farmers to continue to cultivate rice in rainfed areas, such as northeast Thailand, which are increasingly affected by drought. The improved capacity to adapt applies to major irrigated rice areas of China, Pakistan and India, where water supply is forecast to be insufficient to meet demand by 2025. The system can also dramatically reduce methane emissions from irrigated systems as a co-benefit.

Cereal production needs to adopt an ecosystem-based approach to be able increase yields sustainably. FAO's 'Save and Grow' model of agriculture draws on nature's contributions to crop growth. Its five components: conservation agriculture, healthy soils, improved crops and varieties, efficient water use, and integrated pest management, provide sustainable technologies that make efficient use of inputs, protect the environment, build resilience to climate change, and contribute to rural development.

References:

FAO.2016. Save and Grow in practice. Maize, rice, wheat. A Guide to sustainable cereal production. www.fao.org/publications/save-and-grow/maize-rice-wheat/

The full case study: Higher yields from healthy plants in healthy soil http://www.fao.org/3/a-i5305e.pdf

Case 2: Integrated farming systems at landscape scale in Latin America

Location: South America, subtropical warm to moderate cool

Agricultural practice: various integrated practices (e.g. agroforestry, crop and livestock production)

Food and nutrition security: Enhanced

Productivity: Production enhanced and diversified

Resilience: Reduces rural poverty; Improved livelihoods*:* increase of net income: +105 % over the period in 70 properties

Mitigation co-benefit: 12.1 Mt CO_2-equivalent over 661 000 ha in total (0.92 t CO_2-equivalent per hectare and per year in average).

In Santa Catarina (SC) Brazilian state, there is a project focusing on the competitiveness of Family Agricultural Producer Organizations (FAPOs) illustrating how the co-benefits between rural development, sustainable enhancement of the productivity, food security, and agricultural mitigation can be identified and assessed. This project, referred thereafter as "SC Rural" had the objective to increase FAPOs' competitiveness by: (i) providing finance and technical assistance to encourage technological innovation and diversification, as well as raise productivity and broaden market access; and (ii) bolstering the provision of public goods and services, e.g. infrastructure, certification, as well as sanitary, legal and environmental regulatory compliance.

Project components and geographical coverage

The project is complex in terms of components and geographical coverage. It concerns approximately 3.6 million hectares (ha), equivalent to 37 percent of the state's area, characterized by lagging economic performance, potential for improvement and needs for technical and financial assistance. The SC Rural project primarily supports rural agricultural and non-agricultural small-scale producers, rural workers and indigenous families. The beneficiaries are organized in associations, cooperatives, and networks and alliances.

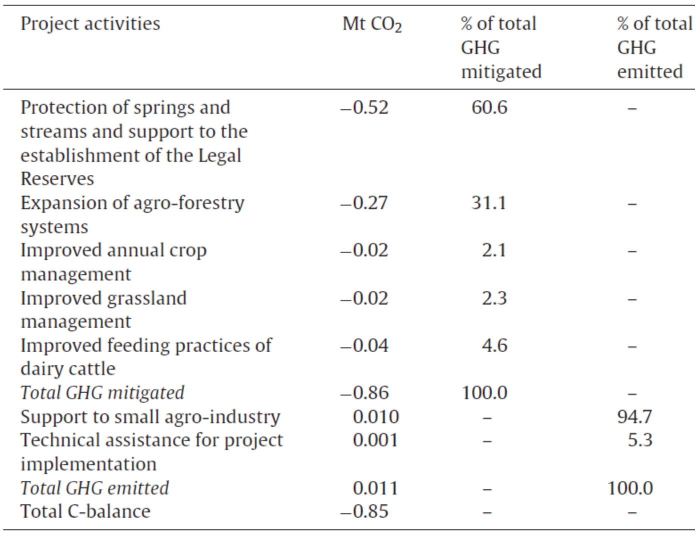
The project objectives included an increase by 30 percent of the total annual sales volume for participating FAPOs. This target was built on preliminary impact evaluation data where a survey of 417 beneficiaries adopting project-financed technologies showed that 86 percent had been able to improve their incomes. Additionally, a detailed monitoring of the evolution of incomes and productivity on 70 properties over two agricultural years found that net income rose 105 percent over the period. Higher productivity and better prices were key determinants.

In terms of mitigation co-benefits, an ex-ante detailed study (Branca *et al.* 2013) estimated the impact of this project on the GHG balance in terms of emissions and sinks. While some project components increase GHG emissions, this is largely compensated by decrease in emissions and increase of carbon sinks in other sectors.

SC Rural activities that have a potential impact on carbon-balance are:

- expansion of training and extension services (pre-investment activities);
- diversification and enhancement of production systems (expansion of perennial crops, promotion of improved grassland and cropland management, and livestock production);
- support to the implementation of small-scale agro-industry and to the construction of sanitary installations;
- rehabilitation of the Areas of Permanent Preservation (Áreas de Preservação Permanente) and Legal Reserve (Reserva Legal) through the protection of existing forests and forest regeneration or rehabilitation (e.g. fencing of riparian areas, agroforestry, planting of native species);
- creation of ecological corridors; and
- rehabilitation of degraded lands.

Table showing mitigation potential (i.e. balance between the project and the baseline), calculated with the FAO The Ex-Ante Carbon-balance Tool, in Mt CO_2-equivalent, of SC Rural by project activity (positive values correspond to net emissions, negative values to sinks or avoided emissions).



Project activities	Mt CO_2	% of total GHG mitigated	% of total GHG emitted
Protection of springs and streams and support to the establishment of the Legal Reserves	–0.52	60.6	–
Expansion of agro-forestry systems	–0.27	31.1	–
Improved annual crop management	–0.02	2.1	–
Improved grassland management	–0.02	2.3	–
Improved feeding practices of dairy cattle	–0.04	4.6	–
Total GHG mitigated	–0.86	100.0	–
Support to small agro-industry	0.010	–	94.7
Technical assistance for project implementation	0.001	–	5.3
Total GHG emitted	0.011	–	100.0
Total C-balance	–0.85	–	–

From Branca *et al.* 2013

A sensitivity analysis considering different scenarios were also realized and showed at the end the SC Rural will most likely be able to also reduce 12.1 Mt CO_2-equivalent in total (0.92 t CO_2-equivalent per hectare and per year in average).

Branca *et al.* (2013) illustrate that a complex rural development project can be successful at promoting activities aimed at reducing rural poverty while contributing to climate change mitigation. The projects entail agricultural intensification and increased productivity, expected to reduce pressure over the native Atlantic Forest.

References:

Branca G., Hissa H., Benez M.C., Medeiros K., Lipper L., Tinlot M., Bockel L., Bernoux M. 2013. Capturing synergies between rural development and agricultural mitigation in Brazil. Land Use Policy, 30, 507-518. http://www.sciencedirect.com/science/article/pii/S0264837712000828

The FAO Ex-Ante Carbon-balance Tool - EX-ACT http://www.fao.org/tc/exact/

Case 3: National climate actions in the Kenyan Dairy Sector: A mechanism for enhancing productivity, food security and improving resilience of dairy supply chains

Location: Smallholder dairy systems, Kenya

Agricultural practice: improved feed and feeding practices, improved animal husbandry and health, management of manure, improved use of energy and cooling and processing of milk

Food and nutrition security: Expected increase in food and nutrition security for over 30 million consumers. Increase in producer purchasing power through increase in income by about US$ 1 000–2 000 per year. Expected increase *in* milk production: 15–20%

Resilience: Improved ability of small-scale farmers to respond with climate and other shocks

Mitigation co-benefit: Potential reduction of 2 million tonnes of CO_2 eq. per annum in 2025

Status: ongoing

The Kenyan dairy sub-sector accounts for 40 percent of the livestock gross domestic product (GDP) and 4 per cent of the national GDP (equivalent to more than US$ 1 billion). The dairy sub-sector contributes to the income of over 800 000 smallholder farmers – mostly women and youth – and generates over 180 000 jobs in the value chain. In general, smallholder farmers own 1–3 dairy cows and produce 80 percent of the Kenyan milk production. Improving milk productivity can thus have positive implications on food security and nutrition and has the potential to reduce poverty, particularly in the rural areas.

The dairy sector in Kenya is characterized by low productivity (average milk yield in Kenya is 600 kg per cow, compared to global average of 2 269 kg per cow in mixed dairy systems), vulnerability to the impacts of climate change and high emissions per kilogram of milk (5.7 kg CO_2 eq./kg milk compared with to global average of 2.8 kg CO_2 eq./kg milk) (Opio, 2013). Improving dairy production and marketing can increase farmers' incomes, improve nutrition in farming families, and increase the efficiency of resource use while reducing greenhouse gas emissions. On a business-as-usual trajectory, Kenya's dairy sector emissions will rise dramatically due to increasing demand for dairy products. Per capita milk consumption in Kenya is estimated at 91 litres per annum and is expected to increase to 220 litres by 2030. It is estimated that there will likely be a "gap" between demand and supply of milk unless the productivity can be dramatically scaled up.

To minimize the impacts of expected rise in sector emissions and achieve carbon neutrality in the sector, the Kenyan Government through the State Department of Livestock and the Kenya Dairy Board with support from Food and Agriculture Organization of the United Nations, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), International Livestock Research Institute (ILRI) and UNIQUE Forestry are developing a national mitigation actions for the dairy sector. The activity is called "Dairy NAMA" (from Nationally Appropriate Mitigation Action) and its aim is to transform the Kenyan sector and significantly reduce GHG emissions while also achieving other social, economic and environmental benefits. The Dairy NAMA is framed within Kenya's national climate change policy and sustainable development goals. It also couples both national development strategies and policy changes, such as the Vision 2030, with the ongoing devolution process to provide a supporting environment for the development of a climate-smart dairy sector.

The key approach envisioned within the Dairy NAMA is to improve dairy productivity and thereby reduce the intensity of greenhouse gas emissions per kilogram of milk, since this allows development of the sector while reducing the environmental impact of growth. Appropriate and cost effective technologies and extension services for fodder production, fodder conservation and farm-based water harvesting technology offer a promising pathway to increase milk production throughout the year. Successful experiences with the East African Dairy Development (EADD) project shows that investments in milk-chilling plants, milk cooperative management capacities and access to commercial processing plants are also important elements to develop the sector. Other key opportunities for climate-smart dairy production will be investigated in the farm input sub-sectors, livestock waste management, energy efficiency improvements in the post-farm-gate value chains and milk processing. Some of these practices and technologies, such as improved fodder, feed conservation, agroforestry, manure management through composting and biogas, and pasture management, and their potential for increasing productivity and reducing GHG emissions, were tested as part of the MICCA pilot project by FAO, ICRAF and EADD. The experience in providing extension and promoting adoption of these practices to small-scale dairy farmers can also inform on the barriers and necessary incentives for the development of a large-scale scheme supporting improvements of the Kenya dairy sector within the Dairy NAMA.

Key activities of the national programme

The NAMA development phase focuses on the following key activities:

- Development of a strong institutional framework through the alignment of dairy NAMA targets with national policies and investment frameworks, establishment of a multi-stakeholder platform, and capacity building of national organizations.
- Capacity development and awareness raising among dairy sector stakeholders about Dairy NAMA development and how they could align their activities with the dairy sector objectives.
- Support the development of the value proposition and investment framework through the identification of cost-effective on-farm technologies and practices; identification and assessment of business models for promoting the on-farm practices and existing finance and investment modalities to integrate climate finance.
- Development of a monitoring and monitoring, reporting and verification (MRV) framework reflecting upscaling requirements of the FAO dairy efficiency methodology currently under validation by Gold Standard.

The NAMA will provide a supporting environment with a financial mechanism to catalyze public and private sector investments that will improve and change current production and management practices. The NAMA will address systemic barriers (such as lack of supporting services and market access, fragmented value chains) to transform the sector and identify key interventions to contribute to the achievement of national development strategies and encourage private sector participation by providing market-led opportunities and incentives, increasing the efficiency and competitiveness of the dairy value chain and supporting a stable milk supply. Initial estimates show a reduction potential of 2 million tonnes CO_2 eq. per annum in 2025, representing about 3.3 percent of Kenya's GHG emissions, and an increase in food and nutrition security for over 30 million consumers. With the application of existing practices and technologies, it is estimated that milk production can increase by 15 to 20 percent. Linking smallholders dairy producers to the market can also increase their income by US$ 1 000–2 000 per year.

The Kenyan dairy NAMA provides a paradigm-shifting approach towards more efficient, productive and resilient dairy development that can be replicated in many smallholder dairy systems both throughout the East African region, as well as in other developing countries.

References:

Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B. & Steinfeld, H. (2013) Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO dairy efficiency methodology (under validation) http://www.goldstandard.org/resources/agriculture-requirements

GLEAM - Global Livestock Environmental Assessment Model www.fao.org/gleam/

Case 4: Sustainably increased aquaculture productivity – Catfish farming in the Mekong delta, Viet Nam

Location: Mekong river delta, Viet Nam, tropical watershed

Agricultural practice: aquaculture, combined with crop production

Food and nutrition security: Strongly improved

Productivity: Strongly improved: Yield *level is* 250 to 400 tonnes per ha/crop. Aprox. 1 kilogram of processed product is derived from 1.69 kg of fresh fish; overall 'waste' was reduced

Resilience: Improved livelihoods: employs 170 000 *people. E*xport income of over US$ 1.4 billion

Mitigation co-benefit: Improved: compared to other fish farming in the region the emission intensity is 1.37 kgCO_2eq./kg live weight fish*;* reduced loss and waste

Other: Developed efficiency, reduced water use, and use of waste water as fertilizer.

The farming of catfish (*Pangasianodon hypophthalmus*) in the Mekong Delta of Viet Nam is hailed as a global success in aquaculture production. The sector currently produces over 1.2 million tonnes in a pond acreage of less than 6 000 ha. It employs over 170 000 people, and in 2009 generated an export income of over US$ 1.4 billion.

This success has triggered the development of subsidiary sectors for feed production, food processing and waste recycling. It is important to note that this boom in production has occurred within a short period of a decade or less. During this period, traditional backyard farming has been transformed into a vibrant commercial activity, with over 97 percent of the final product destined for export to over 100 nations and territories (De Silva & Phuong, 2011).

An increasingly efficient farming system with a comparatively lower carbon footprint

The catfish farming sector is the highest yielding primary production sector. The global average is 250 to 400 tonnes per ha/crop. Only 146 600 tonnes of fish meal and no fish oil is used in the sector. From 2005 to 2010, the processing sector improved significantly. About 1 kilogram (kg) of processed product was derived from 1.69 kg of fresh fish and overall 'waste' was reduced. This waste is not put in landfills and other forms of disposal, but is converted into fish oil and meal. The meal is used as animal feed. At least three of the country's biggest processing plants are involved in this activity.

Catfish farming in Viet Nam has a comparatively low environmental impact. It has also been demonstrated that the overall emissions from 'tra' catfish farming contributed less than 1 percent of total suspended solids, nitrogen and phosphorous in the Mekong Delta as whole. For a sector that produces over a million tonnes of food and generates a revenue in excess of US$ 1 billion, this level of discharge is miniscule (De Silva and Phuong, 2011).

A comparative assessment of GHG emissions of the main farmed fish in Asia; carp, tilapia and catfish shows that the average emissions intensities (EI) from cradle to farm-gate (not including emissions arising from land use change) for catfish in Vietnam was 1.37 kgCO_2eq./kg live weight fish, compared to 1.58 and 1.84 in Bangladesh tilapia and Indian carp respectively. Considering estimated emission values from land use change due to catfish farming are also lower; 1.61 vs 1.81 and 2.12 respectively. (FAO, upcoming technical paper.)

The level of water consumption in catfish farming is much lower than in shrimp farming in ponds. The water and nutrients lost through drainage from aquaculture ponds can be used to irrigate or fertilize crops, either on the dike or in adjacent fields (Prein, 2002). In stagnant systems, such as ponds that are extensively fed or aerated, drainage is irregular and limited at maximum to a few days per year. This makes the use of drainage water from such systems impractical for crop production, unless the drainage water can be stored in a deep reservoir for later use (Mires, 2000).

The sector continues to thrive. It provides a classic example of the effective recycling of waste and has a relatively low-emission scenario compared to most primary production sectors. The Mekong River has the eighth highest discharge of all major rivers in the world. Catfish farming is done in the lower reaches of the delta, which has plentiful water resources. This enables the sector to operate effectively and reap high yields. However, further expansion of the farming area and greater intensification of production may not be possible. A further reduction of the discharge levels to the Mekong River will be the key to the sector's sustainability and this is a major challenge.

Options for adapting catfish farming to climate change

This very productive aquaculture system may not be well prepared to face climate change. Rising sea levels are a real threat in the lower Mekong. The catfish farms may be exposed to increased salinity in the mid and long term.

In the short term, catfish farming may be sensitive to some climate change variability and trends. For example, increasing temperatures and changes in the hydrological patterns may trigger disease outbreaks. A tight biosecurity framework is currently not in place, and given the high density of farms and very high density of fish production, a disease outbreak could devastate the sector.

Catfish farming can become more climate-smart through better planning of farm locations, improved water and nutrient management, and enhanced integration with other farming systems. However, a more urgent measure is a tighter biosecurity framework. Catfish farming can also become more climate-smart by implementing an ecosystem approach to aquaculture through aquaculture management areas (AMAs) (FAO and World Bank, 2015) that would ensure the participation of all stakeholders and improve their understanding of aquaculture related environmental impacts, climate and change-related risks as well as prevention measures. A more long-term approach to adaptation would to breed catfish varieties that are more resistant to salinity.

Reference:

De Silva, S. S. & Phuong, N. T. 2011. Striped catfish farming in the Mekong Delta, Vietnam: a tumultuous path to a global success. Reviews in Aquaculture, 3: 45–73.

FAO Fisheries and Aquaculture Technical paper. Aquaculture contribution to GHG and mitigation measures, in preparation.

FAO. 2013. Climate-Smart Agriculture Sourcebook MODULE 10: Climate-smart fisheries and aquaculture, p. 272 http://www.fao.org/docrep/018/i3325e/i3325e10.pdf

FAO & World Bank Group. 2015. Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. http://www.fao.org/3/a-i5004e.pdf

Mires, D. 2000. Development of inland aquaculture in arid climates: water utilization strategies applied in Israel. Fish. Manage. Ecol., 7: 189–195.

Prein, M. 2002. Integration of aquaculture into crop-animal systems in Asia. Agricultural Systems, 71: 127–146.

Case 5: Integrated food-energy system in Colombia

Location: Colombia, Santander province

Agricultural practice: Integrated crop, agroforestry and livestock production combined with energy production from biogas and solar energy

Food and nutrition security: Improved: varied diets

Productivity: Improved

Resilience: Improved resilience by diverse income sources and energy security; Improved livelihoods (including an annual return of US$ 7 600 for the electricity production)

Mitigation co-benefit: Improved efficiency: use of manure as fertilizer

Other: Improved energy security

An integrated food-energy system in Colombia TOSOLY Farm in the Colombian foothills north of Bogotá, is a highly integrated farm that produces food and energy for family consumption and for sale in a crop and livestock system.

The cropping is based on sugar cane (feed for pigs, food and energy), coffee and cocoa (food and energy), and multipurpose trees. Sugar cane is cultivated on 1.5 hectares of the 7 ha farm. Tree crops include coffee, cocoa, forage trees and forage plants for timber and fuel, including for shading the coffee. The livestock and fuel components are chosen for their capacity to utilize the crops and by-products produced on the farm. The sugar cane stalk is fractionated into juice and residual bagasse. The tops, including the growing point and some whole stalk, are the basal diet for cattle and goats. The juice is the energy feed for pigs and the source of 'sweetener' for the farm family's cooking. The bagasse is the fuel source for a gasifier that provides combustible gas for an internal combustion engine linked to an electric generator. The goats are the means of fractionating the forage trees, consuming the leaves, fine stems and bark as sources of protein. The residual stems are an additional source of fuel in the gasifier. The goat unit has ten breeding does and two bucks. There are three pens for two crossbred cows and their calves, which are kept for the production of milk, meat and manure. The pig unit has a capacity for 40 growing pigs and five sows. Hens and ducks are raised for eggs and meat in foraging, semi-confined systems. Rabbit production, a new venture on the farm, applies the principles of 100 percent forage diets developed in Cambodia, Viet Nam, and the Lao People's Republic. A horse transports sugarcane and other forage.

All high-moisture waste is recycled through plug-flow, tubular plastic (Polyethylene) biodigesters. Pig and human excreta are the feedstock for four biodigesters. Waste water from coffee pulping, washing of dishes and clothes go to a fifth biodigester. Effluents from all eight biodigesters are combined and recycled to the crops as fertilizer. The pens for the goats and cattle have clay floors covered with a layer of bagasse to absorb the excreta. Periodically, this manure is applied to the crops as fertilizer and a source of organic matter.

Most of the energy on the farm (about 100 kilowatt hours per day [kWh/day]) is produced by gasification of the sugarcane bagasse and the stems from the mulberry and Tithonia forages. The 800 W installed capacity of photovoltaic panels are estimated to yield 8 kWh daily. The eight biodigesters produce 6m^3 daily of biogas, two-thirds of which are converted to electricity (6 kWh/day) using it as fuel in the same internal combustion motor generator attached to the gasifier. The remainder is employed for cooking.

Low-grade heat energy produced by the solar water heater and the wood stove are not included in the energy balance. After deducting the electricity used to drive the farm machinery and to supply the house (11 kWh/day), the potentially exportable surplus is 104 kWh daily. At the current price of electricity (US$0.20/kWh), this would yield an annual return of US$ 7 600. Moreover, the gasifier produces 4.4 tonnes of biochar annually, which can be returned to the soil.

Integrated, small-scale farming systems based on multi-purpose crops and livestock, can provide food and feed, without competition between these end uses. The system delivers benefits in terms of food security, productivity, resilience, environment through reduced GHG emissions and improved in soil fertility.

References:

Preston, T. R. 2010. Production of food, feed and energy in a carbon-negative farming system. http://www.mekarn.org/workshops/pakse/html/preston.htm

Preston, T. R. & Rodríguez, Lylian. 2013. Production of food and energy from biomass in an integrated farming system; experiences from the TOSOLY farm in Colombia. http://www.utafoundation.org/papers.htm

Case 6: Gender-sensitive FTT-Thiaroye fish processing technique – Food loss reduction enhancing resilience, food security and productivity for small-scale fisheries

***Location**: Afr*ica (Côte d'Ivoire, Gambia, Ghana, Senegal, Tanzania and Togo) and Sri Lanka

***Agricultural practice**:* efficient fish smoking and drying

***Food and nutrition security**:* enhanced

***Productivity**:* increased in terms of quantity of the products and operators' income, improved in terms of quality and safety of the products; reduced post-harvest loss

***Resilience**:* reinforced resilience for varied weather and climatic conditions, better preparedness, and improved livelihoods

***Mitigation co-benefit**:* the use of the FTT system in lieu of traditional ovens would save a minimum of 734 tCO_2-equivalent for about 26 tons of smoked fish

***Other**:* technology reduced the health, occupational and safety hazards, and improved food safety.

Each year, approximately one-third of all the food produced for direct human consumption is lost or wasted. This enormous waste of resources and investments also represents a threat to food security in the face of population growth and resource scarcity. In low-income countries, food is lost mostly during the early and middle stages of the chain. Climate change may exacerbate food loss because of its negative effects on the supply of raw materials, on processing and storage, and on transport due to extremely high or low temperatures.

Because many smallholder farmers and fishers in developing countries live in food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods. Reducing food loss and waste is also an important step toward developing a more climate-smart food supply chain. In the fisheries sector in low-income countries, losses arise from limitations in production, harvesting, and post-harvesting techniques, storage and cooling facilities, infrastructure, and packaging and marketing systems. Addressing bottlenecks at critical loss points can reduce losses and waste. Improvements in fish processing technologies can address food safety, food loss, sustainability and gender inequalities.

According to the latest statistics, in most fishing communities as many as 90 percent of workers in processing activities can be female (FAO, 2014). Women, therefore, bear the brunt of the drudgery and health problems related to drying and smoking fish. The Thiaroye fish smoking technology (also known as FTT-Thiaroye) improves economic productivity and food security by reducing postharvest losses in the fish value chain. Postharvest losses (in quantity, quality, or marketability) (Diei-Ouadi and Mgawe 2011) lead to a reduction in real incomes and food available for a family.

The FTT-Thiaroye technique was developed by FAO together with the National Training Centre for Fisheries and Aquaculture Technicians in Senegal (CNFTPA) in 2008. The equipment, costing US$500–800, can easily be built by metal workers using local materials. The technology addresses the deficiencies in smoking techniques by adding new components to the existing or improved kilns. The new smoking kiln reduces losses by consistently producing a larger quantity of safer products of superior and more uniform quality.

Essentially, the FTT prevents fish quality losses that become apparent to value-chain actors at the commercialization stage but that actually occur earlier, as a result of inadequate processing technologies in small-scale fisheries. Another advantage of the FTT-Thiaroye system is its improved energy efficiency and other potential environmental protection features. The new kiln reduces charcoal consumption and optimizes the use of biomass (plant and organic by-products and cow dung) throughout the process. In most countries, agro-wastes are easily available. They are not only an affordable alternative fuel, but because they are available within a reasonable distance, their use reduces the labour expended by women in obtaining wood or charcoal for fuel. The technology was recently improved to incorporate a drying function. This improvement made it possible for operators to dry as well as smoke fish with the same equipment, thereby increasing the range of species that could be processed. This important advantage should reinforce processors' adaptation to climate change and increase their resilience, given that the composition of species is projected to change with climate change.

Another significant advantage of the equipment is that fish can be dried or smoked regardless of the weather. Natural drying methods entail postharvest losses ranging from 10 percent to 50 percent (they are generally higher in the rainy season or humid weather). The FTT also contributes to food safety reducing the polycyclic aromatic hydrocarbons (PAHs) carcinogens given off by burning wood.

By design, the FAO-Thiaroye system is a gender-sensitive technique that can be used and maintained easily by female fish processors. By reducing drying and smoking times, and producing a product that sells more readily and rapidly, the new technology increases the time available to women for other pursuits, including caring for the household and children. A more marketable product also fetches premium prices, meaning increased income for the woman who produce smoked and dried fish. The FTT system makes it easy to collect by-products of processing, especially fat, or made into soap, both of which can be sold for additional income. In sum, the technical support by FAO for the FTT-Thiaroye has achieved economic and social dividends, particularly for women, and has contributed to food security.

As a country example, the majority of fish smokers in Côte d'Ivoire are female, and they earn their living through the trade of smoked fish products which are exported to neighbouring countries. In Abobodoumé, instead of using the traditional smoking equipment consisting of mud ovens and cut-up barrels, Ivorian women fish processors adopted two prototypes of the FTT-Thiaroye. By exposing the processors to less heat, fewer burns, and less smoke, the new technology reduced the health, occupational, and safety hazards they experienced, especially the risk to their eyes and respiratory systems. The income and livelihoods of the women also improved, and consequently their capacity to enhance the food security of their family. The women have seen the time-saving advantage of the new technology as well.

Between 2006 and 2011, the European Union banned imports of processed fish from Côte d'Ivoire because of unacceptable levels of polycyclic aromatic hydrocarbons (PAHs) (carcinogens given off by burning wood). The ban caused substantial economic losses valued at around US$1 700 000 per year. With the introduction of the FTT-Thiaroye and its adoption by small-scale processors, Ivorian smoked products have since met the stringent market requirements for PAH levels.

The FTT-Thiaroye is contributing to improving the value chain in the fisheries and aquaculture sector, increasing the competitiveness of the products from small-scale fish operators (especially but not exclusively women), contributing to food security, and strengthening fishing communities' resilience to climate change.

Annex 3: Previous FAO submissions

FAO's submissions to UNFCCC in 2016

FAO. 2016. Concrete opportunities for strengthening resilience, reducing vulnerabilities and increasing the understanding and implementation of adaptation actions

Available at http://unfccc.int/files/documentation/submissions_from_observers/application/pdf/572.pdf

FAO. 2016. Submission C: Adaptation measures taking into account the diversity of the agricultural systems, indigenous knowledge systems and the differences in scale as well as possible co-benefits and sharing experiences in research and development and on the ground activities, including socio-economic, environmental and gender aspects]

Available at http://www.fao.org/climate-change/international-fora/submissions/2016/

All Submissions from FAO can be viewed through:

http://www.fao.org/climate-change/international-fora/submissions/