B10 Developing sustainable food systems and value chains for CSA

Overview

Efforts to promote sustainable food systems that deliver food and nutrition security for all are needed, in ways that support economic development, positive social outcomes and protect the natural environment. This module takes a holistic view of food systems, using a sustainable food value chain approach to identify areas of intervention to adapt to the impacts of climate change and mitigate greenhouse gas emissions, where possible. It considers climate impacts and vulnerabilities at three interlinked levels of the food system: the core value chain; the extended value chain including the support services available; and the enabling environment, including both natural and societal elements. All activities in the core value chain are addressed, including the production, aggregation, processing, distribution, consumption and disposal of food. Chapter B10.2 defines the concepts of food systems and value chains. Chapter B10.3 describes how developing sustainable food value chains involves the careful analysis and weighting of issues related to the economic, social and environmental dimensions, while considering trade-offs and tapping into synergies to achieve the most impactful climate-smart agriculture interventions. Chapter B10.4 identifies the key considerations for selecting food value chains that may be the most appropriate for climate-smart agriculture interventions. Chapter B10.5 proposes possible climate-smart agriculture interventions at all levels of the food system. Chapter B10.6 highlights the need for multistakeholder interventions to develop more sustainable, climate-smart food value chains and food systems.

Key messages

- A food systems approach is needed to design the most effective, proactive and sustainable climate-smart agriculture interventions. This involves an analysis of the food system from farm to fork, including the support services, and the natural and societal elements in the enabling environment in which the food system is embedded.
- Taking a food systems approach helps identify the root causes of vulnerabilities to climate change impacts and excessive emissions and the leverage points that will have the greatest impact for climate-smart interventions in the food system, which in some cases lie in the extended value chain or in the enabling environment, rather than in the core value chain.
- Understanding the interactions of the diverse activities and feedback loops in a food system, as well as the incentives and capacities of the stakeholders involved is critical to optimizing sustainability performance for climate-smart agriculture interventions.
- All environmental, economic and social elements must be carefully considered to minimize trade-offs and harness synergies across food value chains to optimize sustainability for climate-smart agriculture interventions.
- Reducing the carbon footprint of the different stages of food value chains is one of the key elements for ensuring the environmental sustainability of food systems, which is of paramount importance to climate-smart agriculture.
- Developing sustainable food systems that are resilient to climate change and have a reduced carbon footprint will require improved governance and specific and coordinated action from all stakeholders in the food system.
- Governance, which is the vertical coordination of core value chains within food systems, can improve access to technologies, secure financing for climate-smart agriculture interventions and disseminate information about climate-smart agriculture.
- Food system interventions for climate-smart agriculture interventions may include advocating for changes in policies, investing in infrastructure, inputs and services, providing training on best practices, and encouraging behaviour change of all food system stakeholders.

Developing sustainable food systems and value chains for climate-smart agriculture

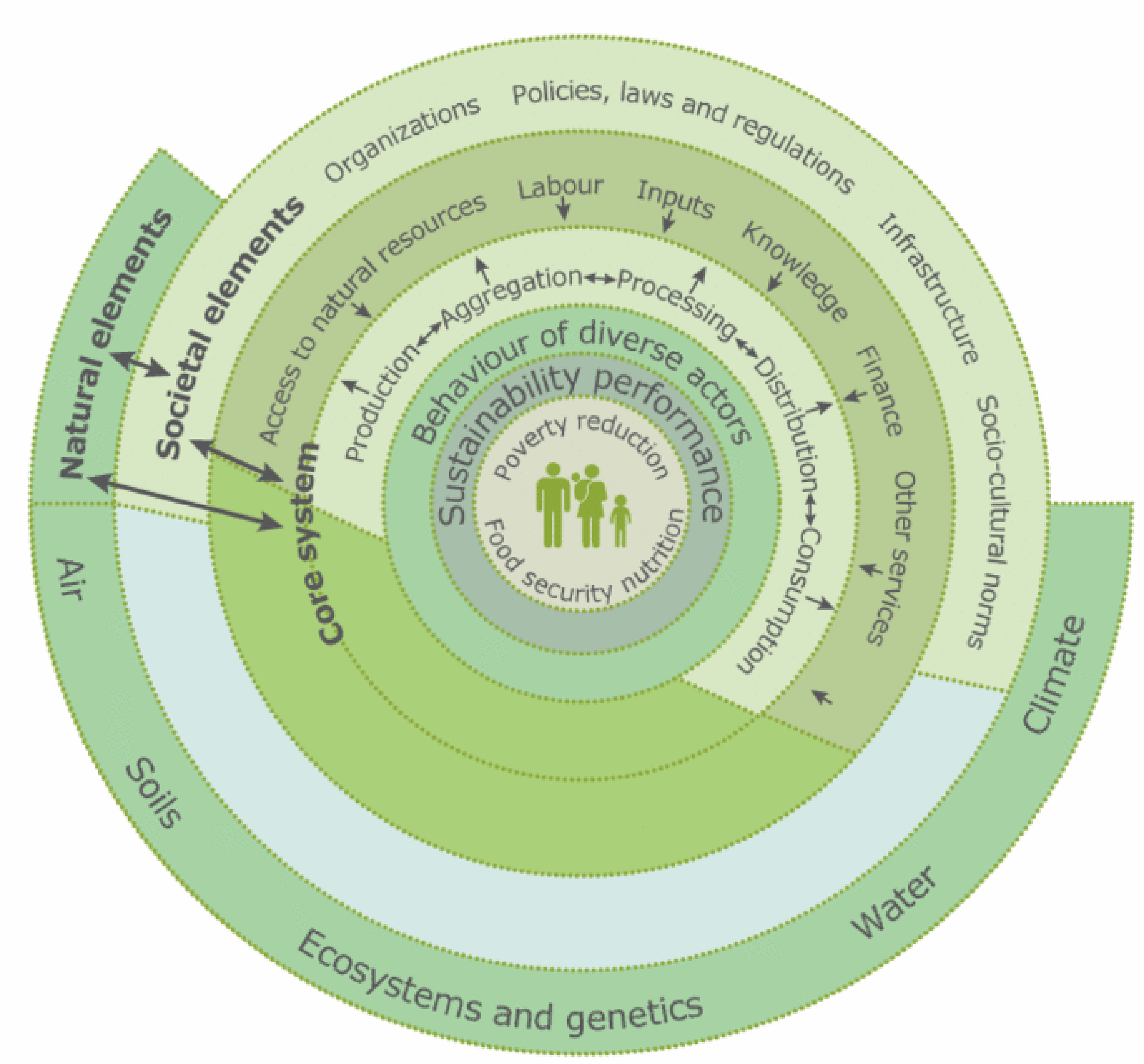
Food systems contribute an estimated 19 to 29 percent of global anthropogenic greenhouse gas emissions. Most of these emissions (80 to 86 percent) are released during the production phase (Vermeulen *et al.*, 2012). However, the relative contribution of global greenhouse gas emissions from food systems is highly variable depending on the region, country, sector, commodity, and production system. Emissions are generated, for example, through the use of fossil fuels across all stages of the food value chains – from production to consumption – that make up food systems, as well as in the extended value chain through the provision of services and inputs (e.g. the manufacturing of chemical fertilizers). Furthermore, the impacts of climate change pose threats to all stages of food value chains and at all levels of the food system. Therefore, each level of the food system presents many opportunities to adapt food systems and their value chains to be more resilient and contribute to increasing global food security. It is important to take a holistic, systems view of the risks and impacts of climate change when designing climate-smart agriculture strategies for sustainable food systems. A systems approach, which involves an examination of the food system as a whole – from farm-to-fork – provides an analysis of the full range of food system activities, the stakeholders involved, and the complex interactions among these activities and stakeholders (Ericksen *et al.*, 2008; Ingram, 2011). This approach can help identify the root causes of the risks and vulnerabilities facing food systems, including those associated with climate change to determine where to focus coordinated, multistakeholder interventions to develop sustainable food systems.

Food systems and value chains: definitions and characteristics

Systems consist of elements and interconnections, and serve a purpose or function (Meadows, 2009). Food systems encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products. Food systems comprise all food products that originate from crop and livestock production, forestry, fisheries and aquaculture, as well as the broader economic, societal and natural environments in which these diverse production systems are embedded (FAO, forthcoming). Activities in the food system also include the provision of inputs and services in the extended value chain, which support (or constrain) the flow of goods through the different stages of the core value chain. These diverse inputs and services may include drought-tolerant seeds, researchers studying climate-smart agriculture interventions, extension services to promote climate-smart agriculture, low-carbon machinery, and climate insurance. Elements in the societal and natural environment in which food production systems are embedded form the enabling environment that influences food systems and will have implications for the design and uptake of climate-smart agriculture interventions. Societal elements include the widespread public perceptions of climate change, specific national plans for climate change mitigation and adaptation (e.g. Intended Nationally Determined Contributions), and global agreements like the Paris Climate Agreement. Natural resources (e.g. land, soil, water, and genetic diversity) and their management, as well as other natural processes, especially those linked to climate, are essential elements of the enabling environment for developing sustainable food systems. The FAO food system wheel (Figure B10.1) depicts the different elements of the food system and the interactions between the various levels.

The overall goals of FAO in developing sustainable food systems are to reduce poverty and ensure food security and nutrition for all, in such a way that does not compromise the capacity of the economic, societal and natural environments to provide food and nutrition security for future generations (HLPE, 2014). Sustainable food systems and the sustainable food value chains (SFVCs) that they comprise are economically sustainable, in that they are profitable; socially sustainable, meaning that they deliver broad-based benefits for society; and environmentally sustainable, such that they have a positive or neutral impact on the environment.

Figure B10.1. Food system wheel – elements and interactions



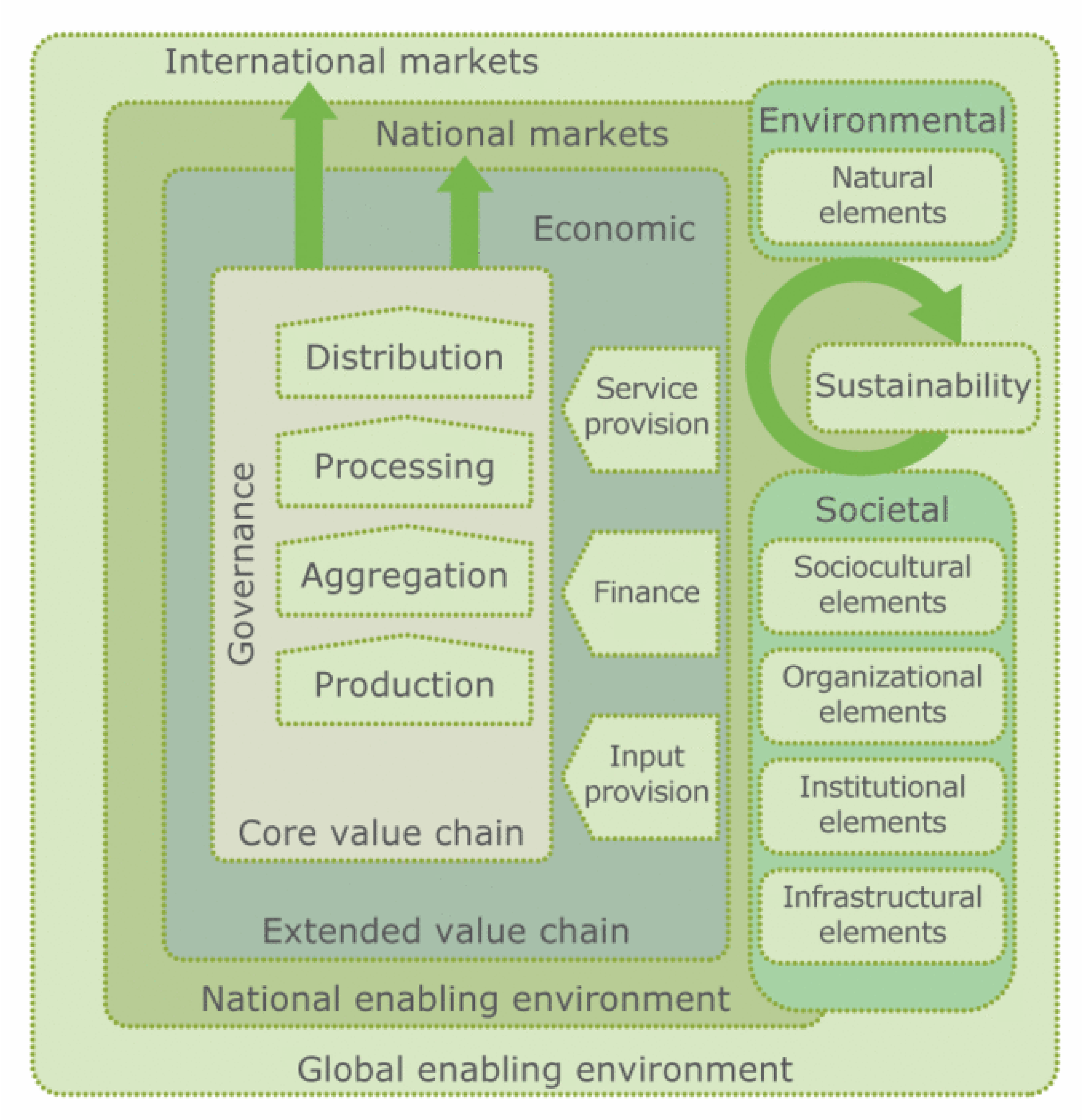
Source: FAO, forthcoming

Understanding food systems and employing systems thinking is critical to identifying the root causes of system failures, including the areas that make food systems vulnerable to climate risks and create inefficiencies that lead to excessive greenhouse gas emissions. It may be possible to introduce climate change adaptation and mitigation measures at each interacting level: the core value chain, the extended value chain and the enabling environment. Taking a systems' view and examining the interaction of all the food value chains within the food system in question can help identify vulnerabilities and formulate resilience strategies. For example, highly connected systems with a disproportionate reliance on a few staple crops from just a few productive regions are extremely vulnerable. On the other hand, greater on-farm diversity, more diversified national food baskets and increases in the number of regions with diversified food baskets could substantially increase the resilience of global food systems (WEF, 2017).

Food systems are composed of subsystems (e.g. farming systems, market systems, waste management systems, and input supply systems) and interact with other systems (e.g. energy systems, trade systems, and health systems). As such, a structural change in the food system might originate from a change in another system. For example, a change in political leadership may have an impact on investments in food systems. Policies that promote biofuels in the energy system will also likely have a significant impact on food systems.

Global, national and local food systems are extremely complex and dynamic, evolving over time. Therefore, it is necessary to conduct an analysis at a workable scale, which can be operationalized through a value chain approach. This type of approach is one of several possible approaches to analyse food systems. Other approaches, which are beyond the scope of this module, include the territorial approach (OECD, FAO, UNCDF, 2016) and a market systems approach (Humphrey, 2014). Figure B10.2 illustrates the FAO sustainable food value chain development (SFVCD) framework. The SFVCD framework takes a dynamic, systems-based approach to measuring, understanding and improving the sustainability performance of the food value chains that make up food systems. It analyses the relationships between the three interlinked layers of the core value chain, the extended value chain and the enabling environment.

Figure B10.2. Sustainable food value chain framework



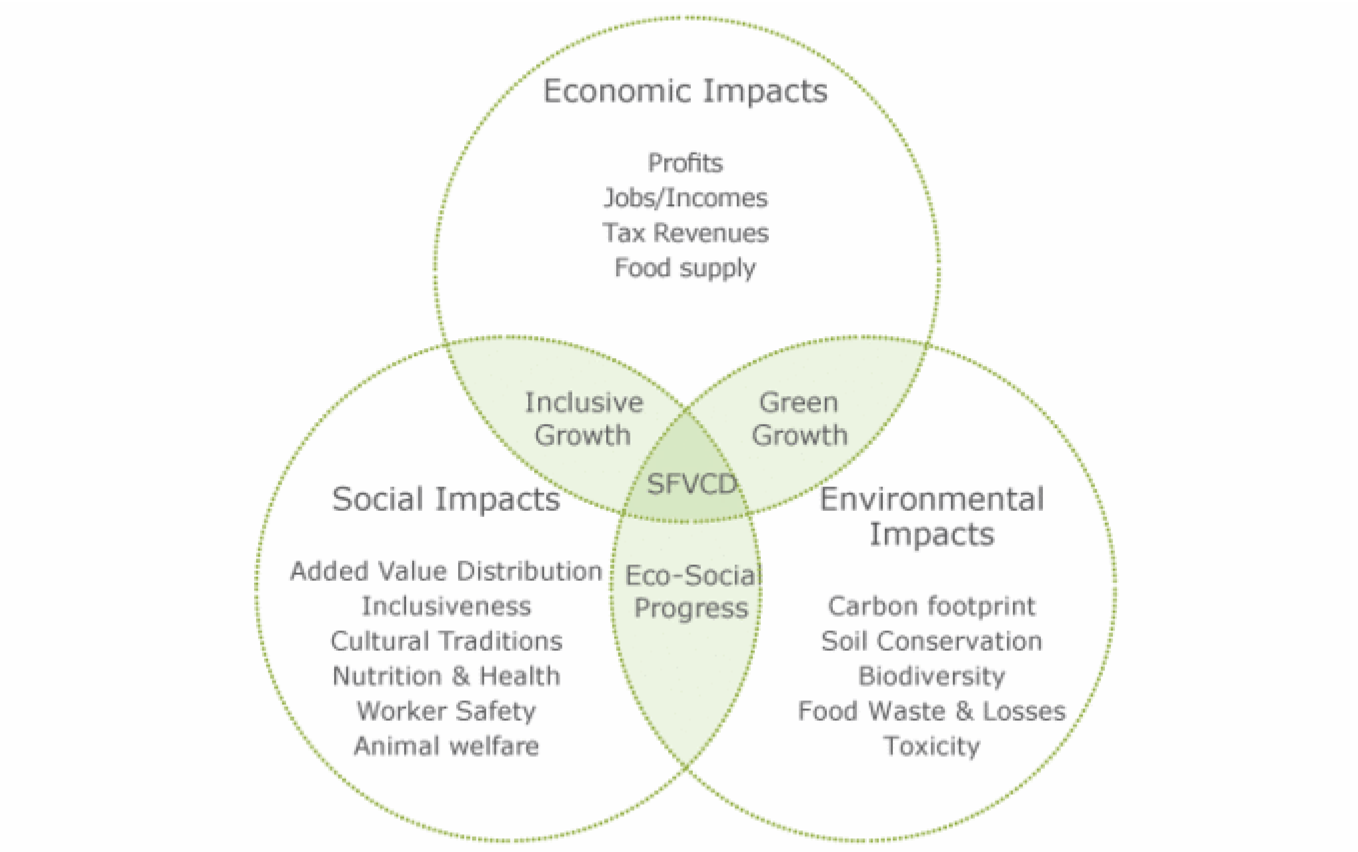
Source: FAO, 2014

Sustainability performance, trade-offs and synergies

Sustainability performance is determined by the behaviour of the diverse stakeholders involved in the food system. All stakeholders shape the overall performance of the food system by adopting certain behaviours, which are determined by their capacities and incentives. The structure of the system influences the behaviour of the stakeholders, and the behaviour of these diverse stakeholders in turn influences the structure of the system, generating feedback loops (Bain, 1956). For example, the development of cold chains has spurred the production and consumption of refrigerator-dependent foods; and the growing presence of refrigerators in homes, particularly in high-income countries, has increased the range of and demand for such foods (Garnett, 2011). Understanding the incentives and capacities of the diverse stakeholders involved in food systems is important when designing effective climate-smart agriculture interventions and expanding their uptake.

The sustainability performance of food systems must be appraised holistically with consideration of the potential trade-offs and synergies in the economic impacts (e.g. incomes, profits, taxes and food supply), social impacts (e.g. gender equality, nutrition, and animal welfare), and environmental impacts (e.g. the conservation of ecosystems, biodiversity, soil and water). In the SFVCD approach, SFVCs occupy the area where the economic, social and environmental dimensions of sustainability intersect, as depicted in Figure B10.3. Developing SFVCs requires the careful analysis and weighting of the economic, social and environmental dimensions of sustainability. Interventions designed based on these analyses will be context-specific and aligned to the priorities of other national climate-smart agriculture programmes. The feasibility of implementation will depend on the capacities and incentives of the various food system stakeholders. In developing climate-smart value chains for sustainable food systems, the priority will likely be placed on reducing negative environmental impacts at all stages of the food value chains, particularly the carbon footprint, as well as improving the resilience of the stakeholders that are the most vulnerable to climate risks. To make food systems more environmentally sustainable and enable them to make a meaningful contribution to global efforts to curb climate change, it is important to examine the carbon footprint of food value chain stages and where possible identify more efficient, less carbon-intensive options.

Figure B10.3. Sustainability dimensions for sustainable food value chain development



Source: FAO, 2014

In value chain development, there will inevitably be trade-offs between the elements within the three dimensions of sustainability (Ericksen, 2008; Ingram, 2011; FAO, 2014). For example, some value chain development projects may deliver economic benefits, such as improved profits and job creation for some food system stakeholders, but have negative environmental impacts, such as changes in land use associated with the conversion of forest land to agriculture. Some interventions, if they rely on a monoculture cropping systems, may have a positive economic impact for some stakeholders, but erode genetic diversity and increase the system's vulnerability to climate change (Alteiri *et al*., 2015). Other interventions may have negative social impacts, such as decreased nutrition, if they promote calorie-rich but nutrient-poor, ultra-processed foods over fresh produce or perishable goods. Equally, food value chain interventions that prioritize environmental elements, such as the reduction of carbon emissions through reduced fertilizer use or the introduction of a new technology, may lead to negative economic impacts in terms of reduced profits and potential job losses, as well as negative social outcomes, such as an unwillingness to embrace the introduction of non-traditional foods.

Climate-smart interventions aim to harness synergies among the different dimensions of sustainability to deliver environmental, social and economic benefits. Climate-smart agriculture interventions may bring additional income to value chain actors and increase their household food and nutrition security; build resilience to market fluctuations; and safeguard ecosystems by protecting biodiversity, reducing soil erosion, and increasing soil carbon sequestration (CGIAR, 2016). To ensure that the outcomes of climate-smart agriculture interventions are sustainable and scalable, it is critical to examine all factors within the economic, social and environmental dimensions of sustainability to minimize trade-offs and capture synergies.

Value chain selection: assessing climate risks and impacts

When developing SFVCs for climate-smart agriculture, it is important to consider both the risks posed by climate change and its impacts. Sustainable food value chains for climate-smart agriculture interventions should be selected on the basis of their vulnerability to climate change; their potential contribution to climate change adaptation and mitigation; and their ability to improve the resilience of producers and other value chain actors (IFAD, 2015). The threats and risks to agriculture posed in climate change projections can be reduced by building the adaptive capacity of producers, increasing the resilience of agricultural production systems at the farm level and beyond, and improving resource use efficiency (Lipper *et al*., 2014).

Some commodities may be more vulnerable than others to the adverse effects of climate change. For example, in Africa, climate change is projected to significantly reduce the area that is suitable for the cultivation of key crops, such as the common bean, maize, banana and finger millet (Ramirez-Villegas and Thornton, 2015). Perishable foods, such as raw fruits and vegetables, may also be more vulnerable to damage during transport and storage. This may lead to more food loss and waste compared to processed foods. However, food processing activities and thus processed foods may also be vulnerable to climate risks due to their greater reliance on potentially unreliable energy supplies (Reardon and Zilberman, 2017). Consideration should be given to interventions to reduce vulnerabilities in post-harvest and processing stages, such as through improved storage (e.g. metal silos) and packaging, which can preserve food and improve the resilience of producers and food value chain actors by reducing their vulnerability to market fluctuations and climate change impacts (e.g. pest infestations).

In addition to variable climate risks, agricultural commodities have different carbon footprints. Livestock production systems for example generate around 14.5 percent of the total global agricultural greenhouse gas emissions. These production systems also have other significant negative environmental impacts on land, water, and biodiversity (FAO, 2012a). Although the amount of meat that is wasted is relatively low compared to other food products, the carbon footprint of meat waste is quite high. The emission intensity (i.e. the amount of emissions per unit of product) of animal-sourced food increases when it goes to waste as the final products encompass all the emissions associated with its production during production, processing, packaging and transport. This includes all the emissions associated with production, (e.g. the methane directly emitted by ruminants), the emissions from the production and provision of feed (e.g. fertilizer application on feed crops), emissions related to manure management, and emissions related to post-harvest activities (e.g. refrigeration, packaging, and transport) (FAO, 2015). Food loss and waste is not only detrimental to food and nutrition security in terms of calories and nutrients lost, it also means that the natural resources that were used and the greenhouse gases emitted during its production are wasted. The decay of food waste after disposal, though relatively small in comparison to the stages from production to consumption, also directly contributes to greenhouse gas emissions (FAO, 2013).

Within food value chain stages and across different commodities there are also significant variations in greenhouse gas emissions. Although it is generally recognized that over half to two-thirds or more of the greenhouse gas emissions from agriculture occur during the production stages (FAO, 2012b), emissions vary depending on the commodity, scale and type of farming operations, transportation methods, and the season. For example, greenhouse gas emissions for milk production, processing and transport have been shown to vary significantly across regions (FAO, 2010). Emissions associated with the transport of most foods over great distances, particularly by air – often referred to as 'food miles' – has been shown to account for a small fraction of overall greenhouse gas emissions from the food system. In some cases, encouraging local consumption can be counterproductive due to the trade-offs that are involved at other stages of food value chains (Garnett, 2011). Nevertheless, transporting perishable foods across borders by plane can make a substantial contribution to greenhouse gas emissions and represents a potential mitigation opportunity (FAO, 2012b).

Box B10.1 Ex-Ante Carbon Balance Tool for Value Chains

The EX-ACT Value Chain (EX-ACT VC) tool is a multi-agent-based tool that appraises all the stages of the value chain stages, including production, transport, and processing, as well as input supply, for all agricultural sectors: crop and livestock production, forestry, fisheries and aquaculture. It uses numerous indicators suitable for developing countries. Designed to consider multiple impacts, it determines performance in terms of: (i) climate mitigation (e.g. greenhouse gas emissions, carbon footprint, the economic returns from climate mitigation actions); (ii) climate resilience; (iii) socio-economic performance (e.g. value added, income and employment generated); and (iv) other environmental indicators (e.g. water use, energy use) of a food value chain. This tool can be used to appraise the current conditions or for value chain development (upgrading) project scenarios.

(Source: FAO, 2017b)

Depending on the situation and the specificity of the analysis required, several methods, including hot spot analysis, life cycle analysis, and carbon footprinting, can be used to identify high priority areas that are particularly vulnerable to climate risks and to assess the relative contribution of greenhouse gas emissions across the stages of food value chains to design effective climate-smart agriculture interventions. Hot spot analysis is a rapid identification tool that uses qualitative information to evaluate sustainability indicators and identify high priority areas (Liedtke *et al*., 2010). For more in-depth, quantitative analyses, a life cycle analysis must be conducted. For example, it may be necessary use a life cycle analysis to quantify the environmental impacts of a potential investment in cold chains, as they may reduce food loss and waste, reduce post-harvest losses and improve food safety (Garnett, 2011).

However, refrigeration is also energy-intensive component in food systems and contributes to greenhouse gas emissions during manufacturing and use, and from refrigerant leakage (Vermeulen *et al*., 2012). Life cycle analyses, which are a useful tool for determining potential climate impacts of interventions and identifying trade-offs and synergies for climate-smart agriculture, can help identify possible options for optimal low-carbon emission strategies. Life cycle analyses determine environmental impacts using a range of indicators, such as water pollution, toxicity, and waste production, across food value chains and food systems. It is also possible to measure the carbon footprint for one item, product or activity across the entire value chain, which is a more specific approach to measuring greenhouse gas emissions (Bockel and Schiettecatte, 2017). The FAO Ex-Ante Carbon Balance Tool for Value Chains (EX-ACT VC), which combines indicators for climate mitigation, resilience, socio-economic performance and other environmental indicators can be useful in measuring value chain performance to support a shift to climate-smart agriculture (see Box B10.1).

Climate-smart interventions

At each level of the food system, there are opportunities to adapt to the impacts of climate change and mitigate greenhouse gas emissions. All stages of the food value chain will likely be affected by extreme climate events associated with climate change and the slow onset impacts of climate change. This requires taking adaptive measures in both the short term and long term. For example, sea level change from climate change over time may affect ports (Antle and Capalbo, 2010), and extreme weather events could damage both roads and other facilities used throughout the post-production stages of food value chains. Very little attention has been paid to ensuring that post-harvest storage and processing facilities, and transport networks are climate-resilient (Antle and Capalbo, 2010; Bendito and Twomlow, 2015). The development of sustainable food systems will only result from using a systems analysis at all levels to design impactful interventions. Climate vulnerability 'hot spots' may lie beyond the core value chain in the extended value chain, or may be linked to the enabling environment (Reardon and Zilberman, 2017). It is critical to examine the entire system to identify hotspots and the key leverage points to implement interventions that will have the greatest impact.

The objectives of climate-smart agriculture – to sustainably increase agricultural productivity and incomes; adapt and build resilience to climate change; and reduce or remove greenhouse gases, where possible – reflect the greater goals of FAO strategic work for sustainable food and agriculture, and can be addressed using a food systems approach. Mitigation may be considered a secondary goal of climate-smart agriculture, after adaptation strategies (Lipper, 2014). However, mitigation remains an important goal, particularly as climate change acts as a negative feedback loop that exacerbates climate risks for those who are already most vulnerable (IPCC, 2007; Foresight, 2011). For example, poorer livestock herders are more likely to suffer the impacts of livestock mortality due to more frequent drought events (Vermeulen *et al*., 2012).

Table B10.1 presents a non-exhaustive list of possible interventions to adapt to the impacts of climate change and mitigate emissions at all levels of the food system. Many climate-smart agriculture interventions cannot be easily categorized as specifically targeting adaptation or mitigation, as these interventions often result in 'win-win' situations that realize both objectives. For example, conservation agriculture enhances soil water retention and increases soil organic matter, which can improve resilience to drought and extreme weather events, as well as soil carbon sequestration. Therefore, conservation agriculture can play a role in both adaptation and mitigation strategies for agricultural production. Interventions in the value chain or in a food system are either directly or indirectly related to elements in the enabling environment, so there is often a clear linkage between these levels. There are some areas of intervention that apply to multiple stages of food value chains and multiple levels of the food system, including reducing food loss and waste and increasing efficiency in the use of resources.

Food loss and waste reduction

Food loss and waste not only squanders the resources used in agricultural production across food value chains, such as inputs like irrigation water, fertilizers, time and energy, it also represents a major source of greenhouse gases. According to the European Commission’s Emissions Database for Global Atmospheric Research, the total carbon footprint of food loss and waste is around 4.4 gigatonnes of carbon dioxide equivalent per year, or about 8 percent of the total anthropogenic greenhouse gas emissions (EC, 2012; FAO, 2015). If food loss and waste was a country, it would be the third largest emitting country in the world, just after China and the USA (WRI, 2012; FAO, 2015). In high-income regions, food loss and waste tends to be higher in downstream stages of food value chains, primarily the consumption stage. In lower-income regions, food loss and waste primarily occurs in upstream stages, such as post-harvest handling, aggregation and storage, and is mostly due to financial and structural barriers in harvesting techniques, storage and transportation (FAO, 2013a; Parfitt *et al*., 2010). It is imperative that strategies are designed for the prevention and reduction of food loss and waste at each stage of the value chain to reduce greenhouse gas emissions of food systems, decrease vulnerability to climate impacts (e.g. relocating storage facilities that are vulnerable to extreme climate events), and to improve food security.

Efficient use of resources

Along with food loss and waste, the efficient use of resources (e.g. fertilizers, water, and energy, food and system waste) is a cross-cutting issue that applies to all levels of the food system and all stages of the food value chains (See case study 10.1). At the production stage, improving efficiency in the use of inputs through sustainable intensification can deliver both adaptation and mitigation benefits (Campbell *et al*., 2014). For example, alternative wetting and drying for rice cultivation, which is a sustainable intensification method that reduces irrigation volumes and can result in increased yields, may potentially be part of adaption strategies for drought-prone environments (Howell *et al*., 2015). At the retail level, the use of refrigeration and refrigerant leakage from refrigerators and freezers has been identified as a substantial contributor to direct greenhouse gas emissions from supermarkets (Garnett, 2011; Ingram, 2011). Reducing refrigerant leakage and improving energy use in the retailing, marketing and distribution of food are examples of potential mitigation measures that can be applied in the post-harvest stages of the food value chain.

Table B10.1. Possible interventions for climate adaptation and mitigation

Value Chain Stage	Adaptation	Mitigation
Production For more information, see: Module B1 on crop production Module B2 on livestock Module B3 on forestry Module B4 on fisheries and aquaculture Module B5 on integrated production systems	- Promote conservation agriculture and sustainable mechanization. - Diversify through agroforestry, intercropping or other diversification strategies. - Utilize improved seed varieties that are adapted to climate change (e.g. drought-resistant, heat tolerant and flood tolerant). - Expand irrigation as appropriate based on water availability	- Promote sustainable soil management practices to improve carbon storage (e.g. conservation agriculture). - Improve fertilizer application practices to increase fertilizer-use efficiency. - Divert animal waste for reuse (e.g. organic fertilizer, biogas production). - Improve water-use efficiency (e.g. through alternate wetting and drying in rice systems)
Aggregation	- Invest in infrastructure and storage (e.g. silos) - Relocate to less vulnerable areas, if necessary	- Reduce food loss and waste by investing in adequate infrastructure - Improve coordination within the value chain to reduce transportation distances
Processing	- Strengthen processing facilities to be able to withstand the potential impacts of climate change (e.g. extreme weather events, pest infestations) - Invest in packaging that maintains quality and safety under climate risks, such as extreme heat	- Reduce energy use (e.g. invest in upgraded energy-efficient processing; use renewable energy sources, where possible)

Value Chain Stage	Adaptation	Mitigation
Distribution and retail	- Improve coordination within the value chain to reduce transportation distances	- Encourage supermarkets to take measures to minimize refrigerant leakage and reduce energy use
Consumption	- Promote local food products for perishable foods	- Reduce food waste at home and in restaurants and catering by encouraging sustainable consumption (see Sustainable Development Goal 12) - Encourage the use of more energy-efficient cooking methods
Disposal	- Weather-proof landfills - Divert more food waste to compost and energy generation	- Invest in improved landfills and more efficient waste collection systems - Reuse and recycle food packaging materials

Food System Level	Adaptation	Mitigation
Extended value chain	- Increase access to insurance for climate risk mitigation - Improve extension services to share knowledge on best practices for reducing climate risks	- Improve extension services to share knowledge on best practices in terms of reducing greenhouse gas emissions (e.g. sustainable soil management) - Provide inputs (e.g. fertilizers and packaging) that are less carbon-intensive
Societal elements	- Encourage public and private sector investments in agricultural research and extension services and infrastructure - Improve roads so that they are more climate-resilient (e.g. drainage for flooding)	- Introduce more energy and resource-efficient cooking methods - Promote recycling, reuse and redistribution - Conduct public health awareness campaigns to discourage overconsumption - Encourage consumers to reduce food waste
Natural elements	- Increase soil carbon and organic matter - Improve water use to restore depleted groundwater - Establish green belts (agriculture and forests) in strategic areas and ensure their protection	- Improve soil carbon sequestration - Discourage the practice of slash and burn

The need for improved governance and multistakeholder approaches

Everyone – including women, men and youth, from agricultural producers and other private sector entrepreneurs, to consumers, researchers and public officials at all levels of government– has a role to play in shaping sustainable food systems. Developing sustainable food systems that are resilient to climate change and have a reduced carbon footprint will require specific and coordinated action from all stakeholders in the food system (Ingram, 2011). This section describes value chain governance and the roles that governments, the private sector, research institutions and consumers must play to support the development of climate-smart value chains for sustainable food systems. Other stakeholders will also play an important role in this regard. Multilateral institutions will be influential in encouraging global climate commitments, supporting governments in meeting national commitments in their development plans (e.g. nationally appropriate mitigation actions), and advocating for climate-smart agriculture policies. Community based organizations and non-governmental organizations will also be instrumental in informing consumers and other stakeholders in the food system about options to reduce food loss and waste through training programmes and public awareness campaigns for example.

Improved Governance

Governance, or the vertical linkages in the core value chain, plays a key role in sustainable food value chain development for sustainable food systems. Governance mechanisms can improve access to technologies, secure financing for climate-smart agriculture interventions and disseminate information about climate-smart agriculture. Since producers are typically the most vulnerable to climate risks of the value chain actors, and the majority of greenhouse gas emissions occur during production, it is important for processors and retailers to work with farmers to develop climate-smart food value chains (World Bank, 2015). For example, processors could play a more active role in shaping resilient food value chains by supplying inputs and providing extension services through contract farming with producers. Additionally, the provision of agricultural insurance and financing that allows farmers to invest in on-farm adaptive capacity would also be a potentially effective option to improving resilience (Campbell *et al.*, 2014; World Bank, 2015).

Government

There is a need to significantly increase agricultural investments to develop sustainable and climate-smart food systems. The government plays an important role in establishing the enabling policy environment to increase both public and private investments in this area (See Box B10.2). Governments must also ensure that infrastructure such as public transportation networks are well-designed and resilient to the impacts of climate change (Bendito and Twomlow, 2015), and that information systems are up to date, can monitor changing climatic conditions and respond to crises. There is also a need for vertical coordination between local, regional, provincial and national governments to ensure coherence in policies that support the development of climate-smart food systems.

Box B10.2 Milan Urban Food Policy Pact and City region food system approach

More municipal governments are realizing their role in developing sustainable food systems. Through the Milan Urban Food Policy Pact, close to 150 cities have committed to working on developing urban food policies to improve their food systems. Important elements, such as urban planning and waste management, are dealt with by the local governments, and they can also use their public procurement power to influence the local food system. The city region food system approach enables local governments to understand their sphere of influence in the food system and work with neighbouring peri-urban and rural communities. A multistakeholder assessment process in this area is being undertaken in Colombo (Sri Lanka), Lusaka and Kitwe (Zambia), Medellin (Colombia), Quito (Ecuador), Toronto (Canada) and Utrecht (Netherlands). An assessment tool kit for local level has been developed for this purpose.

(FAO, 2017a)

Private Sector

The private sector will play a large role in the development of sustainable food systems and value chains by directing investment to making infrastructure, storage facilities, and production, processing and distribution methods more efficient in the use of resources and better able to cope with the impacts of climate change. These investments need to be channelled to post-production stages of food value chains as well as to producers. Agricultural producers, themselves, must take measures to build resilience to climate change by using inputs efficiently and exploring other climate-smart agriculture practices. The private sector can also support innovations in climate risk adaptation and mitigation interventions, improve access to information and extension services, and establish climate insurance schemes, where applicable (Reardon and Zilberman, 2017).

Research Institutions

The promotion of climate-resilient crop varieties and best management practices must be based on research and evidence to improve climate resilience (World Bank and CIAT, 2015). The scientific community can support the development of sustainable food systems by providing information, data and analyses to provide a sound basis for making strategic investments and formulating policies that can make agricultural production systems more efficient in their use of resources, less wasteful in terms of food loss and waste, and less intensive in terms of greenhouse gases emitted per unit of product (iPES Food, 2015; Beddington, 2012).

Consumers

Consumers can play a role in influencing the development of more sustainable food systems and value chains for climate-smart agriculture. They can do this by demanding more environmentally friendly, 'greener' products. Consumers that 'vote with their dollars' for more sustainable food items and adopt more sustainable diets will inevitably trigger upstream effects on the food supply chain, resulting in both diversified food production and processing (FAO, 2012a). Consumers also have a responsibility to mitigate greenhouse gas emissions from the food system. In developed countries, food consumption can account for as much as 15 to 28 percent of national greenhouse emissions. The level of emissions depends on the types of foods consumed (e.g. emission-intensive meat-based foods versus less emission-intensive, plant-based foods), cooking methods, and preferences for foods that are organic, local and in season (Garnett, 2011).

Conclusions

Understanding food value chains and food systems in terms of the risks and the potential impacts of climate change in the core value chain stages, the extended value chain and the enabling environment in which it is imbedded, as well as the behaviour of the diverse stakeholders involved, can help identify the most impactful food system interventions to support climate-smart agriculture. In some cases, the leverage points that will have the greatest influence in promoting a transition to climate-smart agriculture, lie in the support services or the enabling environment of the food system. It is therefore necessary to take a systems approach to identify and design the most effective, proactive and sustainable climate-smart agriculture interventions. Analysing the interactions and feedback loops of the different activities carried out at all levels of the food system and at all stages of the food value chains, as well as the incentives and capacities of the stakeholders involved, can help minimize the trade-offs and harness synergies among the social, economic and environmental dimensions of sustainability. A food systems approach will assist decision making on the potential pathways to follow to develop sustainable food value chains and sustainable food systems for climate-smart agriculture.

Case Study 10.1 Valorization of food waste for developing sustainable food value chains: Composting urban waste into agricultural inputs, Balangoda Urban Council, Sri Lanka

According to the European Commission’s Emissions Database for Global Atmospheric Research, global food loss and waste generates 4.4 gigatonnes of carbon dioxide equivalent annually, or about 8 percent of total anthropogenic greenhouse gas emissions (EC, 2012; FAO, 2015). Minimizing or preventing food loss and waste at the source, as well as reusing safe and nutritious food waste as human food or for high-value non-food consumption (e.g. as animal feed, fertilizer or biomass), would reduce the negative economic and environmental impacts of food loss and waste.

In Sri Lanka, much of the solid waste is openly dumped into waterways and vacant fields in populated areas. Generally, municipal waste collection services are insufficient and only cover the urbanized and commercial areas of cities and towns. Most of the waste that is collected in Sri Lanka ends up in landfill sites, which are usually located close to streams, marshes or forested areas and can harm the environment and public health.

The Balangoda Urban Council in Sri Lanka is one of the oldest local administrations, dating back to 1939. As with many other cities, solid waste management was a key issue for the Balangoda Urban Council. Waste accumulation in the city caused many problems, including unpleasant odours, contamination of water bodies and paddy fields, and gave rise to diseases such as Salmonella, typhoid fever, and diarrhoea. The main objective of the present administration is to build a green and environmentally friendly city by 2025, which includes a waste management project.

Although the composition of municipal solid waste (MSW) in Sri Lanka has a high proportion of organic matter, it also has a high moisture content at about 60 to 75 percent, and a low calorific value at about 1000 to 1200 kilocalorie per kilogram. Due to the low calorific value and high moisture content, the MSW composition is not viable for incineration for energy production. However, MSW with a high organic and moisture content has great potential for composting.

Like many other small- and medium-sized cities in Sri Lanka, Balangoda has introduced a compost plant – with government funding support – to recycle organic waste and produce compost for use in peri-urban and rural agriculture. Most of the compost plants have been established in peri-urban or rural areas, which facilitates the reuse of the compost produced in nearby agricultural areas.

In Balangoda, total MSW collection stands at 20 tonnes per day, with a 100 percent collection coverage. The garbage collected by the urban council is divided into non-degradable garbage (e.g. plastic and glass), which is sold, and non-degradable garbage, which is used to make compost. The compost plant project was initiated in 1999 as a city service to provide a solution to the solid waste management problem, but converted into a business later. Integrated waste management in Balangoda now consists of an MSW compost plant, a septage treatment plant, plastic pelletizer and an open dumping ground. The Balangoda Composting Plant recycles MSW, faecal sludge, fish waste, and slaughterhouse waste, with a capacity of 14 tonnes per day. In 2005, a waste-purchasing centre was built with support from the municipality to buy non-degradable waste from the city. In 2008, a night soil (i.e. human excrement that is collected at night from cesspools for use as manure) treatment plant was established. The current revenue stream of the plant is now made up by the sale of the compost from MSW and 'super compost' from the night soil. The quantity of organic fertilizer produced by the plant has increased from 2 620 kilograms in 2003 to 385 660 kilograms in 2009. Income generated in 2009 from fertilizer sales (1 345 660 Sri Lankan Rupees) was over 100 times the income generated in 2003 (13 100 Sri Lankan Rupees). The income collected by selling recyclable goods in 2003 was 75 450 Sri Lankan Rupees and increased in 2009 to 432 650 Sri Lankan Rupees (Cofie and Jackson, 2013).

City dwellers benefit from the improved waste management system and reduced health risks by reducing direct contact with untreated waste in informal dumping sites. Farmers around Balangoda benefit from the production of organic fertilizers. This recycling of urban waste resources to benefit peri-urban and rural agriculture constitutes an effective strategy for operationalizing urban-rural linkages. The plant brings additional income to the municipality and the economic benefits are shared between the municipality and the seventeen plant workers.

In spite of the increased sales of compost, the compost produced by the project is not competitive with chemical fertilizers, which are heavily subsidized. A 50 kilogram bag of chemical fertilizer at the subsidised rate is cheaper than a 50 kilogram bag of the compost. As chemical fertilizers have a higher concentration of essential plant nutrients, the chemical fertilizer can be applied in smaller quantities than compost. The comparative advantage of the compost produced by the Balangoda plant lies in its ability to improve the quality of the soil, which is particularly important given the sandy soils in the province. Chemical fertilizers leach out of the soil without a soil conditioner, such as compost. Awareness raising and training to educate the public and farmers on the benefits of integrated waste management and the use of compost are indispensable for improving the uptake of this sort of initiative.

Source: GIZ, FAO and RUAF, 2016

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Acronyms

MSW	municipal solid waste
SFVC	sustainable food value chains
SFVCD	sustainable food value chain development

References

Altieri, M.A., Nicholls, C.I., Henao, A. & Lana, M.A. 2015. Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development*, 35(3): 869-90.

Antle, J.M. & Capalbo, S.M. 2010. Adaptation of Agricultural and food systems to climate change: An economic and policy perspective. *Applied Economic Perspectives and Policies*, 32(3): 386-416.

Bain, J. 1956. *Barriers to New Competition*. Cambridge, Massachusetts: Harvard University Press.

Beddington, J.R., Asaduzzaman, M., Clark, M.E., Fernandez Bremauntz, A., Guillou, M.D., Jahn, M.M., Lin, E., Mamo, T., Negra, C., Nobre, C.A., Scholes, R.J., Sharma, R., Van Bo, N. & Wakhungu, J. 2012. The role for scientists in tackling food insecurity and climate change. *Agriculture & Food Security*, 1:10.

Bendito, A. & Twomlow, S. 2015. Promoting climate smart approaches to post-harvest challenges in Rwanda. *International Journal of Agricultural Sustainability*, 13(3): 222-239.

Bockel, L. & Schiettecatte, L.S. 2017. *Life Cycle analysis and the carbon footprint of coffee value chains*. Rome.

CGIAR. 2016. *Are climate-smart agricultural practices economically desirable?* [Online]. [Cited: 28 September 2017].

Campbell, B.M., Thornton, P., Zougmoré, R., van Asten, P. & Lipper, L. 2014. Sustainable intensification: What is its role in climate smart agriculture? *Current Opinion in Environmental Sustainability*, 8: 39-43.

Cofie, O. & Jackson, L. 2013.*Thematic paper 1: Innovative experiences with the reuse of organic wastes and wastewater in (peri-) urban agriculture in the global South, Supurbfood project*. RUAF Foundation. Leusden, the Netherlands.

European Commission (EC). 2012. *Emission Database for Global Atmospheric Research*, version 4.2. Joint Research Centre (JRC).

Ericksen, P.J. 2008. What is the vulnerability of a food system to global environmental change? *Ecology and Society*, 13(2): 14.

FAO. 2010. *Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment*. Rome.

FAO. 2012a. *Greening the Economy with Agriculture*. Rome.

FAO. 2012b. *Improving Food Systems for Sustainable Diets in a Green Economy – Working Paper 4 – Utilization*. Rome.

FAO. 2013. *Food wastage footprint: Impacts on natural resources - Summary Report*. Rome.

FAO. 2014. Developing Sustainable Food Value Chain. Guiding Principles. Rome.

FAO. 2015. Food wastage footprint and climate change. Rome.

FAO. 2017a. Food for the Cities Programme: Building Food Secure and Resilient City Regions. Rome.

FAO. 2017b. Practical Guidance on the use of EX-ACT for Value Chain (EX-ACT VC). Rome.

Foresight. 2011. *The Future of Food and Farming: Challenges and choices for global sustainability- Executive Summary*. London: The Government Office for Science.

Garnett, T. 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy*, 36(1): S23-S32.

German Agency for International Cooperation (GIZ), FAO & RUAF. 2016. Composting urban organic waste into agricultural inputs. In: M. Dubbeling, C. Bucatariu, G. Santini, C. Vogt, K. Eisenbeib. *City region food systems and food waste management: linking urban and rural areas for sustainable and resilient development*. Bonn: GIZ, pp. 172-181.

High Level Panel of Experts on Food Security and Nutrition (**HLPE).** 2014. *Food losses and waste in the context of sustainable food systems* (No. 8). CFS Committee on World Food Security HLPE.

Howell, K., Shrestha, P. & Dodd, I. 2015. Alternate wetting and drying irrigation maintained rice yields despite half the irrigation volume, but is currently unlikely to be adopted by smallholder lowland rice farmers in Nepal. *Food and Energy Security*, 4(2): 144-157.

Humphrey, J. 2014. *Market systems approaches – A literature review*.

International Fund for Agricultural Development (IFAD). 2015. How to do climate change risk assessments in value chain projects, Rome.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Ingram, J. 2011. A food systems approach to researching food security and its interactions with global environmental change. *Food Security*, 3(4): 417–431.

International Panel of Experts on Sustainable Food Systems (iPES). 2015. The new science of sustainable food systems: Overcoming barriers to food systems reform.

Organisation for Economic Co-operation and Development (**OECD), FAO & UN Capital Development Fund (UNCDF).** 2016. *Adopting a Territorial Approach to Food Security and Nutrition Policy*, OECD Publishing, Paris.

Liedtke, C., Baedeker, C., Kolberg, S. & Lettenmeier, M. 2010. Resource Intensity in global food chains: the Hot Spot Analysis. *British Food Journal*, 112(10): 1138-1159.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P. et al. 2014. Climate-smart agriculture for food security. *Nature Climate Change*, 4(12): 1068–1072.

Meadows, D. 2009. *Thinking in systems: A primer*. London: Earthscan.

Parfitt, J., Barthel, M. & Macnaughton, S. 2010. *Food waste within food supply chains: quantification and potential for change to 2050*. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554): 3065-3081.

Ramirez-Villegas, J. & Thornton P.K. 2015. *Climate change impacts on African crop production. CCAFS Working Paper no. 119*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.

Reardon, T. & Zilberman, D. 2017. Climate Smart Food Supply Chains in Developing Countries in an Era of Rapid Dual Change in Agrifood Systems and the Climate. In L. Lipper, N. McCarthy, D. Zilberman, S. Asfaw, G. Branca. *Climate Smart Agriculture: Building Resilience to Climate Change* (Eds). Springer, USA.

Vermeulen, S.J., Campbell, B. M. & Ingram, J.S.I. 2012. *Climate change and food systems*. Annual review of environment and resources, No. 37.

World Bank. 2015. *Future of food: Shaping a climate smart global food system*. Washington D.C.

World Bank & CIAT. 2015. *Climate-Smart Agriculture in Rwanda. CSA Country Profiles for Africa, Asia, and Latin America and the Caribbean Series*. Washington D.C. World Bank Group.

World Economic Forum (WEF). 2017. *Shaping the future of global food systems: A scenarios analysis*.

World Resources Institute (WRI). 2012. *Climate Analysis Indicators Tool*.