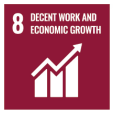

Agriculture in the Face of Climate Change: Sustained and Inclusive Economic Growth as a Prerequisite for Sustainable Development

Romano De Vivo, Ettore Capri, Henri Rueff, Antonio Gaudioso, Alexandru Marchis and Gianpiero Menza

1. Introduction

Climate change and weather extremes are already impacting millions of people, devastating crops, eroding coastlines, and threatening freshwater reserves. A continued build-up of greenhouse gas (GHG) pollution is expected to lead to warming, more acidic oceans and a continued rise in the sea level, changed weather patterns, and an even more significant threat to supplies of food, water, and fish (IPCC 2014). The food and agriculture sector is particularly vulnerable and will be hit in multiple ways (FAO 2016a).

According to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, the effects of climate change on crop and food production are already visible, reducing yields, mainly for wheat, maize, and rice,[1] in some parts of the world (IPCC 2014). A further rise in temperatures will likely exacerbate such effects. Food production will be impacted by climate change itself, as well as related issues such as water availability, pests, and disease. While there may be some positive effects, the most likely results are very worrying and are expected to have environmental, social, and economic dimensions (IPCC 2019).

This is particularly true in emerging economies, where the food and agricultural sectors (agri-food) make a significant contribution to economic performance: smallholder farmers and the rural poor in such areas appear to suffer even more due to the limited resilience and diversity of production (FAO 2015a). Climate change is expected to reduce soil resilience and increase the vulnerability of products and producers, and destabilize markets with higher price volatility (Chatzopoulos et al.

[1] In cereal production, "there is evidence that climate change has already negatively affected wheat and maize yields in many regions and at the global level. The IPCC warns that decreases in crop yields of 10 to 25 per cent and more may be widespread by 2050". Furthermore, "the increased frequency of warmer nights in most regions is … impacting rice yields and quality" (FAO 2017a).

2020). If producers are not flexible enough to shift and adapt quickly to changing crop suitability, we can, for instance, expect increased migratory pressure, with people moving away from farming and into cities and even across borders (IPCC 2014). That is, if not dealt with properly—and quickly—climate change will hinder the achievement of vital goals for human development: it threatens to undermine and maybe even reverse recent progress in the fight against poverty, hunger, and malnutrition (UN 2019a).

Still, we can only expect effective measures if all stakeholders—individual farmers as well as governments, research institutions, advisors, providers of technical solutions, and the financial sector—increase and coordinate their efforts (McKinsey and Company 2015).

Decisive, ambitious measures could help agriculture to better handle expected changes but also serve to create synergistic effects between climate and development goals. The right measures could even help keep global temperatures in check. The sector contributes significantly to emissions—about 10 to 12 percent of human-made greenhouse gases (GHG) are produced by the agriculture sector. The sector is the main contributor of non-carbon dioxide greenhouse gases (e.g., methane), the primary source of agricultural emissions, coming from the digestive process of livestock and stored animal manure. It also emits large volumes of nitrous oxide from fertilizers, whereas the post-harvest stages of the production chain emit significant amounts of GHGs, as do food loss and waste (FAO 2015b).

Climate-smart agriculture (CSA), an expression coined by the Food and Agriculture Organization of the United Nations (FAO 2017b), pursues three main objectives—sustainable increase in agricultural productivity and income, greater resilience of food systems, and the reduction of emissions associated with agriculture—that may best help address climate change and meet development goals.

There are already ongoing efforts to engage business in CSA. The World Business Council for Sustainable Development (WBCSD) has launched an initiative to test large-scale projects in five pilot regions of the world (WBCSD 2015).

The US Agency for International Development (USAID) is working with the Sustainable Food Lab (Sustainable Food Lab 2019)—a global network of organizations looking to work towards a more sustainable food system—and coffee and cocoa partners, including private companies, to develop a learning community that provides business cases, strategies and action plans for the engagement of agribusiness in CSA.

The FAO has also launched the Global Alliance for Climate-Smart Agriculture (GACSA) to help create transformational partnerships on CSA. The Alliance is an action-oriented multistakeholder platform that brings together national governments,

growers, scientists, business and civil society, as well as international organizations to discuss and learn about on-ground solutions and policy mechanisms combating climate change in the agricultural sector (GACSA 2014).

Lastly, the World Bank has been investigating supply chains (World Bank 2015) to highlight concrete examples of how farmers and food companies can work together to build more resilient models.

The critical challenge, though, is how to integrate business models when most potential actions increase costs and reduce returns in the short-term, while even the medium-term benefits remain uncertain. Who will finance or invest in the needed changes? Encouraging agribusinesses requires new incentives and perhaps a combination of hard and soft laws, including regulations and subsidies. We need to figure out how to introduce incentives that businesses will adopt: it is unlikely that the sector will make the necessary changes independently.

This paper aims to facilitate the business contribution to transforming agri-food systems to become more climate-smart. We lay out the threats, possible approaches and, finally, propose hard and soft policies that may help guide the sector into the right direction while promoting the United Nations' Sustainable Development Goals (SDGs) (UN 2015). It is critical for the business to play a role early on in this multistakeholder process: this will help ensure that the legitimate concerns of all actors are taken into account (WRI 2015).[2]

What is the best way then for the private sector to support this transformation? Business involvement can be founded on several areas of social and economic inclusion and environmental sustainability, and the SDGs provide a useful framework. They provided a breakthrough for businesses in providing a structure for guiding overall sustainability targets and indicators. SDGs help enterprises create principles, codes, and voluntary commitments to eradicate poverty and hunger, sustain responsible production and consumption, tackle climate change, and ultimately promote sustained, inclusive, and sustainable economic growth.

Sustained and inclusive economic growth (SDG 8) is a prerequisite for sustainable development and contributes to improved livelihoods, new and better employment opportunities, and greater economic security. The agriculture sector is the basis and

---

[2] Partnerships will become increasingly essential for transformative goals, i.e., for those that tackle systemic problems, remove barriers, change established dynamics and implement long-term solutions. New models of cooperation are emerging based on multi-stakeholder platforms that facilitate the dynamics of collaboration between industrial actors, policymakers, academics, researchers and citizens. These models provide food for thought on how the involvement of a broad interdisciplinary audience can open up new opportunities for sustainable development (WRI 2015).

the most vulnerable part of this growth, and transforming it to deal with new contexts and dramatic changes requires a more comprehensive vision that implies a broader transformation of the rural economy (WRI 2018; World Bank 2020). Addressing the socio-economic and environmental challenges related to climate change and making progress towards SDG 8 requires a concerted effort from all actors. Businesses have started to act in certain areas but, given the enormity of the challenge, need to do much more and need to be supported in their efforts by a system of policies and an enabling environment of multistakeholder collaborations.

2. Threats of Climate Change to the Food and Agriculture Sectors

A growing number of businesses fear that the effects of climate change may disrupt their supply chains and their ability to grow in a sustainable and profitable way. The biggest threats are likely to come from menaces to food security, nutrition, and human health, genetic resources, and agrobiodiversity[3], and land degradation, as detailed below (Stockholm Resilience Center 2010). At the same time, the global food system is a significant emission contributor with up to a third of total emissions. The Global Sustainable Development Report (UN 2019b) clearly states that feeding the global population in 2050 under current agricultural practices poses significant threats to the Paris Agreement and other Sustainable Development Goals, while agriculture supports livelihoods and employs over 1.1 billion people (Independent Group of Scientists appointed by the Secretary-General 2019).

2.1. Food Security, Nutrition and Human Health

According to the FAO, food security relates to food availability, access, utilization, and supply-chain stability, and climate change threatens to undermine them all (FAO 2017a). Food availability will likely be affected by declining yields in the crop, livestock, fisheries, and aquaculture sectors. For instance, crop yields in Brazil could fall by up to 70 percent for soybeans and up to 50 percent for wheat with a warming of 2 °C (World Bank 2014a, 2014b). The IPCC warns that average yield reductions of 10 to 25 percent by 2050 could be widespread (FAO 2017a).

The International Food Policy Research Institute (IFPRI), in its report "Climate Change: Impact on Agriculture and Costs of Adaptation" (IFPRI 2009), predicts that

---

[3] "The impact on biodiversity, along with nitrogen levels, has already entered the warning stage for surpassing what our planet can manage. These factors must be addressed jointly with climate mitigation and adaptation throughout the full value chain of the agricultural sector" (Stockholm Resilience Center 2010).

rice productivity will decrease by 14% in South Asia, 10% in East Asia and the Pacific and 15% in sub-Saharan Africa by 2050. This would lead to price increases of between 32% and 37% (IFPRI 2009). The impacts will vary not only by crop but also by region depending on factors including latitude and irrigation.[4] To give some examples, estimates suggest that the United States could see a 20% drop in corn production, particularly in mid-Western states, whereas Brazil's corn production could decline by nearly 16% by 2050.

Some of the most significant impacts of global climate change will be felt in developing countries among "subsistence" or "smallholder" farmers. Their vulnerability stems both from being mainly located in tropical areas and from various socio-economic, demographic, and political trends that limit their ability to adapt to climate change. For instance, climate change can affect crop rotations, so growers have to consider new crop varieties, sowing dates, cropping density, and fertilization levels when growing crops to achieve sufficient yields for a growing population. These are all challenging pursuits for smallholders. Food accessibility will likely be hit by diminished purchasing power. This is because impacts on production have carry-on social and economic effects that come from fluctuations in agricultural incomes and prices, which also affect trade and investment. A proper evaluation of the economic cost of land degradation should also take into account factors including environmental vulnerability, demographic pressures, economic dependence on land, social and political instability, and the international context (Dupont 2015) and commitments, all of which can amplify the extent of the impact of degradation (UNCCD 2015).

Climate change is expected to have an impact on food utilization, mostly through food safety and health.[5] It can reduce food safety by making food-borne diseases more widespread. It can also affect health in multiple ways, including geographical shifts in some diseases, heat stress, and natural disasters. The foreseen increases in the frequency and intensity of climate-related events are expected to undermine food stability. All of these effects are likely to affect nutrition by changing the composition of diets as well as available calories (Stockholm Resilience Center 2010).

---

4 If less water is available, soil better able to retain water will be more resistant to drought.

5 In general, climate change is likely to reduce food safety through a higher incidence of food-borne diseases. Climate also affects health via multiple pathways, including geographical shifts in vector-borne diseases, heat stress and natural disasters, which in turn affect the nutrition of people and their ability to provide care as well as nutritional contents of food.

2.2. Genetic Resources, Agro-Biodiversity, Water and Soil

The number of crop varieties declined significantly in the 20th century, and intensive monoculture systems have expanded worldwide (FAO 2017a). These trends threaten adaptive capacity, increase genetic vulnerability and reduce nutritional diversity, leading in turn to lower resilience among agro-ecosystems and livelihoods (Bioversity International 2013; FAO 2020).[6] This situation is further exacerbated by climate change: increased temperatures and the scarcity of water make it challenging to conserve both crop and wild plant genetic resources (FAO 2017a).[7]

Climate change also poses significant threats to natural resources that are vital for farming. Such damage and depletion undermine the ecological processes that support healthy, productive landscapes, and climate change may become the leading cause of biodiversity loss (WRI 2005). For instance, soils, the basis for plant growth, are deteriorating and are lost at significant rates due to the adverse effects of climate change. What is more, loss of soil fertility is associated with loss of carbon in the soil. This destabilizes the soil and reduces its buffer and storage capacity for nutrients and water; it also means that soil degradation is a source of carbon dioxide (CO_2) emissions. The loss of soil carbon reduces farmers' resilience to climate change and increases atmospheric CO_2 (FAO 2017a).

3. Addressing Climate Change in Agriculture

Climate change is a global issue requiring locally adapted responses (FAO 2016b). Businesses must help make agricultural systems less vulnerable, secure the sustainable provisioning of food and support the livelihoods of those who produce it.

Addressing the threats mentioned above means transforming agri-food systems so that they become increasingly more efficient, use resources more wisely, and are more resilient to risks, shocks, and long-term climate variability while protecting and enhancing biodiversity (FAO 2017a). All actors in the value chain must also make efforts to reduce the emissions associated with the business itself. For instance, post-harvest phases use over 70 percent of the energy and release around 30 percent

---

[6] It is estimated that of a total 300,000 plant species, 10,000 have been used for human food since the origin of agriculture. Out of these, only 150–200 species have been commercially cultivated of which only four—rice, wheat, maize and potatoes—supply 50 per cent of the world's energy needs, while 30 crops provide 90 per cent of the world's caloric intake (FAO 2010).

[7] "Climate change is projected to significantly reduce renewable surface water and groundwater resources with particular intensity in most dry subtropical regions. Many regions are likely to face substantial water scarcity" (FAO 2017a).

of the greenhouse gases of the entire agri-food value chains (excluding those resulting from land-use change) (FAO 2011; Garnett 2011).[8] In addition, food loss and waste are responsible for about 8 percent of global GHG emissions (FAO 2015b, 2017b). If the sector can, at the same time, reduce carbon emissions and promote sequestration, such changes could represent an enormous opportunity to support both climate and development goals. While it is not clear who should pay in the face of low carbon prices, business needs to take a leadership and coordination role in dealing with the challenges. Hence, agriculture (SDG 2 coupled to SDG 15) has the potential to support a number of ecosystem services, including mitigation and adaptation to climate change, giving it a strong co-benefit leveraging effect across other SDGs such as SDG 13, SDG 8, and SDG 4.

Businesses using both adaptation measures and mitigation potential should advocate on behalf of food security and nutrition as well as environmental, social, and economic sustainability for growers at the global level. What is the best way to do this?

Climate-Smart Agriculture Approach

While many alternative sustainable strategies have been developed over the years, they all strive to maintain productivity and usefulness to society over the long run. Sustainability is a process rather than a prescribed set of practices and generally supports the convergence of all the available technologies and their use in solutions able to address local needs and societal requirements. In our opinion, attempts to maintain growing, predictable harvests with as little fluctuation as possible should not compromise the structural integrity or resilience of the production system. Management and conservation of resources such as soil and water should remain a priority while taking energy inputs into account.

The FAO's Climate Smart Agriculture approach has been introduced to guide the transformation of agricultural systems, safeguard food provisioning, integrate adaptation, mitigation, and food security. It provides an inclusive policy framework for a wide range of farming interventions in different contexts and could help us redesign and reorient agri-food systems to effectively support the development and

---

[8] What are the best ways for reducing greenhouse gas emissions in the food system? The analysis done by Garnett showed that around half of the food sector emissions came from agricultural production, and the other half came from: manufacture of synthetic fertilizers (5%), food processing (12%), packaging (7%), transport (12%), retail (7%), home food preparation (9%), catering (6%), food waste disposal (2%) (Garnett 2011).

safeguard food security in a changing climate (FAO 2017a). It aims to maximize benefits, pursue synergies and manage trade-offs across the three main CSA objectives of improving productivity, building resilience, and reducing emissions associated with agriculture.

The approaches could allow us to support an increase in crop productivity through the good management of soil, water, and biodiversity and help adapt the livelihoods of people likely to be affected by climate change. We can support agricultural practices contributing to reduced emissions, deforestation, and the degradation of land. The combination of soil and weather maps giving precise information about local meteorological conditions, soil type, and restorative need can help optimize local soil treatment to be more efficient, retain more carbon, reduce leakages of nutrition as well as improve water irrigation schemes.

Integrating Climate Smart Agriculture into business models could help the sector protect its supply chains, grow sustainably and profitably, all while meeting its commitments to reduce its impact on the environment.[9] This could also address the concerns of some investors and large commercial banks beginning to establish strict investment criteria.

4. How Businesses Can Contribute to Climate-Smart Agriculture

What is the best way then for the private sector to support CSA? While it is clear that the private sector has a range of technologies, a depth of knowledge, and appropriate diagnostic tools and can help to channel substantial climate financing into agricultural systems, an overarching, coherent, and locally adapted approach is needed.

Business' involvement can be founded in several areas of social inclusion and environmental sustainability, and the UN's Sustainable Development Goals (UN 2015) provide a useful framework. They have provided a significant step forward for companies in delivering a framework to guide their overall sustainability objectives and indicators. SDGs help businesses create "soft laws" or business standards such as codes of sustainability, principles, and voluntary commitments to ensure that their operations are sustainable. CSA could help businesses to set targets that support SDGs: SDG 1 on ending poverty, SDG 2 on ending hunger; SDG 8 on economic

[9] The World Business Council for Sustainable Development CSA initiative has convened a group of companies from the agri-food sector to address the double challenges of climate change and the need to meet the food needs of a growing world population (WBCSD 2015, 2020).

growth; SDG 12 on responsible production and consumption, including the reduction of food waste; and SDG 13 on tackling climate change.

Climate change erodes food security, nutrition, poverty reduction, and sustainability in many ways, and agribusiness should be encouraged to focus its climate change strategy on improving food security and nutrition. Working within such a framework and following a harmonized approach for sustained, inclusive, and sustainable economic growth will require prioritized action. More concretely, agribusinesses can help support such goals in the following ways:

4.1. Increase the Uptake of Digital Agriculture

Consumer preference for sustainable food on the one hand and increasingly demanding access to capital on the other is putting pressure on farmers to manage their resources efficiently and accountably in order to maintain a competitive advantage over the long term.

Digital or precision agriculture—simply defined as translating agronomic advice into better and more precise execution of farm operations and applications to the field using equipment and machinery, usually through map-based digital systems—is one way in which they can do this. Digitalization can improve forecasting, diagnose pests and diseases, provide apps to measure wind speed, and improve spraying. In general, it gives us a chance to reach out to a vast number of farmers (WEF 2016).

Precision farming technologies, including the use of drones, soil sampling, probes, high-efficiency irrigation, and GPS-enabled machinery, could combine field and soil information with weather and product data to provide an integrated, intelligent strategy in the field. The customized, real-time, finely tailored, thoughtful insights gathered can help growers tackle intra-field variability, make smart choices on what to plant, when to plant, where to plant and what to apply to the plant and soil, and increase production efficiency while reducing resource degradation and carbon emissions.

Agribusinesses could help farmers adopt precision agriculture practices through consolidation across the food value chain, new cooperative ways of investing, and new finance and risk-sharing models that favor them. However, commercial models are mainly available, because of the required investments, in developed countries.

The opportunities to leapfrog current developments are, therefore, more significant in the least developed countries, but this will require new service delivery models that build on what is available to make innovations more accessible and affordable. This entails more investment and innovation, testing, and demonstrations. Famers will need to provide more data, but more data should also be made available

to them. We will also require improved and tailored information services that offer longer-range weather forecasts and information on changing cropping and farming protocols.

4.2. Build Smallholder Farmer Resilience

Agriculture research companies need to develop specific technologies such as seeds that are more resistant to disease, drought, and flooding to meet the needs of smallholder farmers. For example, genetic advancement in certain crops well suited to small-scale farming, such as dietary staples including cassava, savory types of bananas, sorghum, and millet, could help promote food security in the context of a changing climate through local self-sufficiency and reliance. Doing this requires that agribusinesses include the correct measures in innovation scorecards so that they can make the right choices in the research and development process.

In addition to research, the sector could promote new business models and approaches to support smallholder farmers at all stages of the production value chain. There are many examples of new business approaches that fit the needs of smallholder farmers. These include finance and risk-sharing models, trading partnerships, small and affordable package sizes, and cooperative input distribution, models. Sustainably scaling up these models will provide new opportunities for agribusinesses.

4.3. Promote Ecosystem-Based, Connected Landscape and Conservation Agriculture Approaches

Ecosystems services help build resilience and mitigate the vulnerability to the effects of climate change on communities and their livelihoods. Integrating the protection of biodiversity and ecosystem services into adaptation and mitigation strategies and conserving genetic resources increases the resilience of food and agriculture systems to risks. Strategies to address climate change should be better aligned with attempts to protect biodiversity and ecosystems.

For instance, creating connected landscapes with healthy, functioning ecosystems can help rehabilitate degraded land and maintain the biological flows and infrastructure needed to increase the resilience of agriculture to drought and other climate impacts. Landscape connectivity would, therefore, not only help build resilience against climate change but also sharpen our attention and dedication to the triple goal of people, planet, and profit (De Vivo et al. 2016; WBCSD 2017).

In a similar way, no-till methods of soil management enhance the water retention capacity of the soil and prevent soil erosion by incorporating crop residues into

the surface and minimizing carbon losses in the soil. They can also reduce the fuel consumption associated with cultivation by 60 to 70 percent (FAO et CABI 2006).

4.4. Improve Nutrient Management

Crops rely on soil nutrients (e.g., fertilizers, organic amendments, and N-fixation) and re-cycled inputs from the remains of crops left in the field. Optimizing fertilizer use efficiency in crop production can minimize nutrient losses to the environment while increasing nutrient delivery to the target crops. For example, the use of smart fertilizers can either delay the release of nutrients for uptake or transform nutrients into other forms that are less susceptible to loss. Categories of products that improve fertilizer efficiency include the controlled release of nitrogen fertilizers, nitrogen stabilizers, and phosphate management products. New services for efficient nutrient management may also be an opportunity and can consist of soil analysis (soil pH to optimize the availability of nutrients to crops, as well as organic matter), crop variety-optimized fertilizer application rates, and weather forecasts to optimize the application. Optimizing and supplementing the supply of nutrients to crops with fertilizers, the use of organic amendments, and the remains of crops/ cover crops left in the field are essential to soil health (FAO 2006).

4.5. Reduce Food Loss and Waste

Global food losses are enormous. The FAO estimates that about one-third of all cultivated food is lost due to pests, deterioration, waste, ineffective processing or transport, inefficient logistics, and consumer preferences (FAO 2017b). Businesses could encourage joint efforts and the prioritization of a framework for food loss and waste mitigation based on nutritional, environmental, and social indicators. This could help value chain actors such as those involved in packaging, processing, post-harvest handling, and distribution to evaluate options for reducing food waste along the value chain, taking into account infrastructure needs and constraints. It could also help businesses set standards and protocols for reducing food waste, as well as defining targets and action plans to achieve them. Since reasons for losses vary around the world, local and regional analyses should form the basis of any action plans.

In addition, the private sector, NGOs, and local authorities should help raise consumer awareness against food waste. One way of doing it is via food labeling and by supporting social awareness campaigns. It is also possible to use feedback loops to increase consumer understanding of who has produced the food and under what

circumstances. This approach to traceability can address nutritional needs, as well as expand cultural approaches to food, facilitating access to more healthy diets.

Food waste poses as well substantial equity issues, more so when considering that food waste goes parallel, with 2 billion people suffering from food insecurity (Independent Group of Scientists appointed by the Secretary-General 2019).

4.6. Seek Multistakeholder Support

The CSA approach requires the assistance of multiple stakeholders to identify optimal interventions. They should, at the same time, take social, economic, and environmental constraints and opportunities through the entire food value chain into consideration (FAO 2017a). We nonetheless need to recognize that businesses are best organized through value chains in which all parties have something at stake.

Businesses could align with and seek the support of governments, academics, and civil society organizations at appropriate levels to roll out their CSA strategies. For instance, companies could engage with global climate-related initiatives such as the Global Alliance for Climate-Smart Agriculture to strengthen dialogue and partnership with NGOs and other stakeholders (Acosta et al. 2019; World Bank 2014a, 2014b; McCarthy et al. 2018).[10]

4.7. Measure and Evaluate the Impact

Businesses will also need to make an effort to measure and assess the actions they introduce as well as results achieved. This will involve gathering data and evidence to better inform policy and investment decisions on the links between food security, nutrition, and climate change (FAO 2019). Better knowledge and capacity to analyze the impacts of climate change on food security and nutrition and on agri-food can improve the measures taken.

Companies will need to support and strengthen decision-making based on the lessons learned from sectoral and cross-sectoral analysis of information, data, and knowledge. Common frameworks for measurement and outcomes should also be established (TFCFD 2017).

---

[10] The list of global and regional multi-stakeholder initiatives is impressive, as is the diversity of fields of action and approaches: ISF, the Smallholders Finance Initiative; the World Cocoa Foundation; the Round Table on Sustainable Palm Oil; the Global Coffee Platform; and IDH, the Sustainable Trade Initiative; to name some, but a few.

4.8. Endorse Platforms to Share Knowledge and Foster Learning on CSA

Businesses could help develop CSA knowledge-sharing platforms to facilitate learning and access to the latest information in the fast-evolving and multi-faceted field of climate change. These platforms, designed with partners throughout the value chain or with local authorities, could help to increase individual and collective awareness and knowledge, as well as improve education on mitigation, adaptation, impact reduction, and early warning for the private sector (CGIAR 2020). Companies might also set up agri-food centers to provide farmers with the necessary technology, education, and advice. These centers can be part of established state agricultural extension services or new units created to enable farmers to learn practices from each other. They could also help to achieve economies of scale by combining collection and storage from several farms. The centers allow new ideas, technologies, and business models to spread rapidly, and they can work with financial institutions to offer loans. The centers could also be used to provide timely weather information to promote improved on-farm weather monitoring and reduce risk. Tools to help farmers and advisors to see climate-related risks and potentials of their individual farms need to be further developed and made available to all farmers. This will include developing the capacity of institutions to collect data and the formation of international data and analysis to assist increasingly integrated and efficient agri-food systems (UNDP 2020).

4.9. Build Innovative Financing Models to Support CSA

According to the International Financial Cooperation, access to adequate financial resources is crucial for the creation of a market for CSA, but farmers rarely have access to credit, as the financial institutions regard them as a high risk. Adopting CSA requires up-front investment, which often takes time to lead to productivity gains. In addition, market premiums for sustainable products rarely offer adequate margins to finance climate-smart investment programs (IFC 2017). Businesses could help educate and encourage financial institutions on the business models for CSA to identify opportunities to increase investment. There is also a more general need for innovative financing and ways to cut risk. This could include first-loss facilities, insurance, capacity building, structured markets, social impact bonds, etc.

Farming should be understood as a provision of services rather than just food. By doing so, farmers could be incentivized and receive financial support for their actions towards ecosystem services. By doing so, policies activating this approach could actually cover a wide range of SDGs from “No Poverty SDG 1”, “Zero Hunger SDG 2”, “Good Health and Well-Being SDG 3”, “Decent Work and Economic Growth

SDG 8", "Climate Action SDG 13", "Life Below Water SDG 14", to "Life on Land SDG 15".

For this to happen, farmers and pastoralists need better regulation and access to markets, including infrastructure such as processing plants and producer cooperatives (Rueff and Rahim 2016). Adaptive capacities in adjusting market requirements to support quality farming and livestock producers may ease uncertainties and constraints for exporting farming goods. In the meat sector, for example, commodity-based trade allows healthy animals originating from foot and mouth contaminated areas to be exported nevertheless when deboned (Rueff and Rahim 2016).

4.10. Introduce Index-Based Insurance

Index-based insurance is a scheme covering smallholders for losses due to climate hazards. Policyholders are compensated according to an index of hazards (i.e., drought indices) and not on actual losses. This principle keeps an incentive for policyholders to still work towards saving their production and acting against a hazard when possible while being compensated, unlike conventional schemes. With conventional programs, policyholders would have no incentive to protect their output since the greater the losses, the higher the compensation (Rueff and Rahim 2016).

5. Conclusions

The agriculture sector is particularly vulnerable to potential threats from climate change and variation and must be prepared to adapt. Decisive measures could help agriculture face expected changes, help keep global temperatures in check and serve and create synergies between climate, development goals, and sustained inclusive growth.

Businesses have a significant potential to reduce greenhouse gas emissions and increase carbon sequestration in the soil while contributing to food security objectives and meeting key goals of human development. Boosting the operational efficiency and productivity of food production systems through improved technologies and better management practices can significantly contribute to reducing the footprint of global agriculture. To this end, agribusinesses should support and endorse the CSA approach to help small and large-scale farmers tackle changing climatic conditions by maximizing crop yields while using less land and non-renewable natural resources. The private sector can help by developing both conventionally bred and genetically modified seeds, chemical and biological pesticides as well as a range of adjacent technologies and practices.

At the same time, addressing societal challenges related to climate change and making progress towards SDG 8 requires a concerted effort from all actors. Businesses have started to act in certain areas but, given the enormity of the challenge, need to do much more to support CSA and need to be supported in their efforts.

5.1. Addressing Climate Change with Hard and Soft Laws

We must pursue ambitious approaches to both adaptations and to cutting emissions.[11] New public policies promoting CSA as a means of addressing such challenges are critical instruments for achieving collaboration and coherence in actions.

We argue that such policies should be developed in two parallel tiers. On the one hand, we need policies that directly target agricultural actors, stimulating farmers to implement appropriate mitigation and adaptation technologies and management practices. On the other, we need policies that create an enabling environment for other actors and sectors to contribute to the implementation of the CSA indirectly.

5.2. Policies Directly Targeting Agricultural Actors

These sorts of policy options can be grouped into those that rely on either legislative, economic, or social levers. Legal interventions allow for the introduction of requirements and mandatory management standards, pushing agricultural actors to adapt their technologies and management practices. Nonetheless, their efficiency in generating the necessary change depends on mechanisms, instruments, and tools to verify and ensure their enforcement. Options include setting rules on the management of resources (land, water, emissions) or managing the impacts on the environment and human health.

The economic lever can be used to create a pull effect on agricultural sector actors by providing compensation for additional costs or financial incentives to act in the desired way. The extent and scope of such policies are dependent on the public resources available and on the mechanisms in place to check the delivery of the desired results. They can be an excellent option to promote certain practices (e.g., conservation agriculture, biodiversity corridors, water harvesting, etc.) or can be considered when the change in agricultural practices delivers on certain public

---

[11] Possible mitigation opportunities include land management, food loss and waste reduction and reducing emissions from land-use change and livestock.

goods (e.g., food security, water management, pest control, landscape management, air quality, etc.).

Social-lever policies represent a softer approach and relying on raising awareness and education, in general, on the social organization of the community. While results are usually only visible over the long term, the impact is embedded in the fabric of society.

5.3. Policies Creating an Enabling Environment

We also need policies that create an enabling environment for other actors and sectors to indirectly contribute to the successful implementation of CSA.

Research and innovation policy has a vital role in developing new and improved solutions for agricultural production and for successfully contributing to the establishment of CSA. Such measures include adapting crops to new geographical zones or making them more resistant, developing machinery for precision agriculture, or IT systems that make better use of farming data and satellite technology. Their development should not rely solely on public research but also on new policies that encourage private companies to invest resources to develop economically sustainable products and technologies. To this end, companies must be provided with the appropriate economic and regulatory environment to allow them to control and manage the risks associated with such investments.

Appropriate policies should encourage and support public–private partnerships and multistakeholder collaboration platforms: they help spread the burden and reduce individual risks in the development of the appropriate solutions for the implementation of the CSA. Multistakeholder collaboration also enables the development of standards and guidelines necessary for implementing desired actions, all without creating risk imbalances in the value chain (Figure 1).

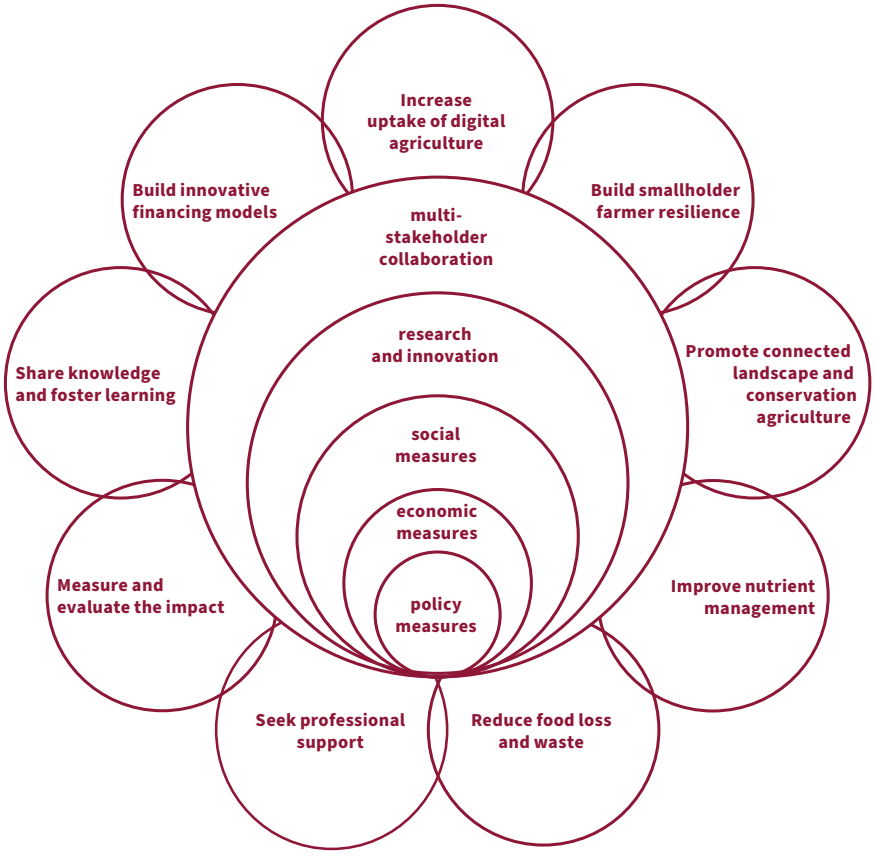

Figure 1. Elements that interplay in promoting CSA to addressing climate change and driving inclusive economic growth. Source: Figure by authors.

5.4. Recommendations

Given the complexity of the challenges related to climate change and the different ways in which agriculture can respond, a mix of policies should be considered. This will ensure a stable and fair common ground for all actors while encouraging them to adjust their strategies and operations to cope with the emerging threats.

At the country level, the recent adoption of the SDGs provides an opportunity to create such an enabling framework. Considering policy options for agriculture within a more general policy approach to making progress on the SDG 8 ensures that decisions are taken on a commonly accepted ethical and practical framework for individual and collective action. It also ensures that there is a common baseline.

Companies should, therefore, consider aligning their strategies and operations to work towards the SDGs, thus acting in sync with the general objectives of society. In doing so, products, solutions, and technologies will be aligned to the future needs of their clients and will empower other actors and sectors to create sustained and inclusive economic growth benefitting us all.

Transformative change through the 2030 Agenda will likely be achieved by applying an SDG interconnectedness approach. Some SDGs do have a leveraging co-benefit effect, while others present trade-offs across a series of SDGs. Policy coherence and effectiveness will be achieved if food security and agriculture options take into account their strong leveraging effect, but also addressing the trade-off that they can have when it comes to climate change and land degradation, if not adopting a CSA approach (Pham-Truffert et al. 2020; Newell et al. 2019).

Author Contributions: All authors have contributed significantly and substantially to the intellectual content of the article. RDV played the role of the lead author by preparing the first draft. All co-authors have reviewed and approved the manuscript, at least as it pertains to their roles in the project.

Funding: This research received no external funding.

Acknowledgments: I would like to thank Isabelle Schluep (CCRS) for the review and valuable feedback on the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

Acosta, Mariola, Edidah Lubega Ampaire, Perez Muchunguzi, John Francis Okiror, Lucas Rutting, Caroline Mwongera, Jennifer Twyman, Kelvin M. Shikuku, Leigh Ann Winowiecki, Peter Läderach, and et al. 2019. The Role of Multi-Stakeholder Platforms for Creating an Enabling Climate Change Policy Environment in East Africa: Investigating the Business of a Productive, Resilient, and Low Emission Future. In *The Climate-Smart Agriculture Papers*. Edited by Todd S. Rosenstock, Andreea Nowak and Evan Girvetz. Cham: Springer, pp. 267–76.

Bioversity International. 2013. Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health. Available online: https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Diversifying_food_and_diets_1688_02.pdf (accessed on 15 May 2020).

CGIAR. 2020. Climate-Smart Agriculture 101. Available online: https://csa.guide/csa/contact#main-index (accessed on 15 May 2020).

Chatzopoulos, Thomas, Ignacio Pérez Domínguez, Matteo Zampieri, and Andrea Toreti. 2020. Climate extremes and agricultural commodity markets: A global economic analysis of regionally simulated events. *Weather and Climate Extremes* 27: 100193. [CrossRef]

De Vivo, Romano, Alexandru Marchis, Emilio J. Gonzalez-Sanchez, and Ettore Capri. 2016. The Sustainable Intensification of Agriculture. *Solutions Journal* 7, pp. 24–31. Available online: https://www.thesolutionsjournal.com/article/sustainable-intensification-agriculture/ (accessed on 15 May 2020).

Dupont, Cedric. 2015. Policy cycle: Developing a comprehensive approach. Paper presented at UNCCD COP12, Ankara, Turkey, 1 October 2015.

FAO. 2006. Plant Nutrition for Food Security: A Guide for Integrated Nutrient Management. Available online: http://www.fao.org/3/a-a0443e.pdf (accessed on 15 May 2020).

FAO. 2010. The State of Food Insecurity in the World Addressing food insecurity in protracted crises. Available online: http://www.fao.org/3/i1683e/i1683e.pdf (accessed on 15 May 2020).

FAO. 2011. Energy-Smart Food for People and Climate. Available online: http://www.fao.org/docrep/014/i2454e/i2454e00.pdf (accessed on 15 May 2020).

FAO. 2015a. Voluntary Guidelines to Support the Integration of Genetic Diversity into National Climate Change Adaptation Planning. Available online: http://www.fao.org/3/a-i4940e.pdf (accessed on 15 May 2020).

FAO. 2015b. Food Wastage Footprint and Climate Change. Available online: http://www.fao.org/3/a-bb144e.pdf (accessed on 15 May 2020).

FAO. 2016a. Climate Is Changing. Food and Agriculture Must Too. Available online: http://www.fao.org/3/a-i5758e.pdf (accessed on 15 May 2020).

FAO. 2016b. The State of Food and Agriculture. Climate Change, Agriculture and Food Security. Available online: http://www.fao.org/3/a-i6030e.pdf (accessed on 15 May 2020).

FAO. 2017a. Strategy on Climate Change. Rome. Available online: http://www.fao.org/3/a-i7175e.pdf (accessed on 15 May 2020).

FAO. 2017b. The Future of Food and Agriculture: Trends and Challenges. Available online: http://www.fao.org/3/a-i6583e.pdf (accessed on 15 May 2020).

FAO. 2019. *Climate-Smart Agriculture and the Sustainable Development Goals: Mapping Interlinkages, Synergies and Trade-Offs and Guidelines for Integrated Implementation*. Rome: FAO, Available online: http://www.fao.org/3/ca6043en/ca6043en.pdf (accessed on 15 May 2020).

FAO. 2020. Climate-Smart Agriculture Sourcebook. Available online: http://www.fao.org/climate-smart-agriculture-sourcebook/concept/module-a1-introducing-csa/chapter-a1-5/en/ (accessed on 15 May 2020).

FAO et CABI. 2006. No Tillage Seeding in Conservation Agriculture. Available online: http://www.fao.org/3/a-al298e.pdf (accessed on 15 May 2020).

GACSA. 2014. Strategic Plan 2018–2022. Available online: http://www.fao.org/3/CA1216EN/ca1216en.pdf (accessed on 15 May 2020).

Garnett, Tara. 2011. *Where Are the Best Opportunities for Reducing Greenhouse Gas Emissions in the Food System (Including the Food Chain)? Food Climate Research Network*. Guildford: University of Surrey.

IFC. 2017. Creating Markets for Climate Business: An IFC Climate Investment Opportunities Report. Available online: http://www.ifc.org/wps/wcm/connect/974eedcb-f3d9-4806-b32e-73720e6f4ca7/IFC-Climate_Investment_Opportunity_Creating_Markets.pdf?MOD=AJPERES (accessed on 15 May 2020).

IFPRI. 2009. Climate Change: Impact on Agriculture and Costs of Adaptation. Available online: http://www.ifpri.org/publication/climate-change-impact-agriculture-and-costs-adaptation (accessed on 15 May 2020).

Independent Group of Scientists appointed by the Secretary-General. 2019. *Independent Group of Scientists appointed by the Secretary-General, Global Sustainable Development Report 2019: The Future Is Now—Science for Achieving Sustainable Development*. New York: United Nations.

IPCC. 2014. *Fifth Assessment Report. Agriculture Forestry and Other Land Use (AFOLU). in Climate Change 2014: Mitigation of Climate Change*. Cambridge: Cambridge University Press, Available online: https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter11.pdf (accessed on 15 May 2020).

IPCC. 2019. Special Report on Climate Change and Land. Available online: https://www.ipcc.ch/srccl/ (accessed on 15 May 2020).

McCarthy, Nancy, Leslie Lipper, and David Zilberman. 2018. Economics of Climate Smart Agriculture: An Overview. In *Climate Smart Agriculture. Building Resilience to Climate Change*. Edited by Nancy Leslie, Nancy McCarthy, David Zilberman, Solomon Asfaw and Giacomo Branca. Cham: Springer, vol. 52, pp. 31–47. [CrossRef]

McKinsey and Company. 2015. Investing, vol. 2, Global Agriculture's Many Opportunities. Available online: http://bit.ly/2k47dCk (accessed on 15 May 2020).

Newell, Peter, Olivia Taylor, Lars Otto Naess, John Thompson, Hussein Mahmoud, Patrick Ndaki, Raphael Rurangwa, and Amdissa Teshome. 2019. Climate Smart Agriculture? Governing the Sustainable Development Goals in Sub-Saharan Africa. Frontiers in Sustainable Food Systems. Available online: https://www.frontiersin.org/articles/10.3389/fsufs.2019.00055/full (accessed on 15 May 2020).

Pham-Truffert, Myriam, Florence Metz, Manuel Fischer, Henri Rueff, and Peter Messerli. 2020. Interactions among Sustainable Development Goals: knowledge for identifying multipliers and virtuous cycles. *Sustainable Development*. In press. [CrossRef]

Rueff, Henri, and Inam Rahim. 2016. Enhancing the economic viability of pastoralism: The need to balance interventions. *Revue Scientifique et Technique* 35, pp. 577–86. [CrossRef] [PubMed]

Stockholm Resilience Center. 2010. Planetary Boundaries. Available online: http://www.stockholmresilience.org/research/planetary-boundaries.html (accessed on 15 May 2020).

Sustainable Food Lab. 2019. Available online: https://sustainablefoodlab.org/the-climate-smart-agriculture-papers/ (accessed on 15 May 2020).

TFCFD. 2017. Climate-Related Financial Disclosures. Available online: https://www.fsb-tcfd.org/ (accessed on 15 May 2020).

UN. 2015. Sustainable Development Goals (SDGs). Available online: http://www.un.org/sustainabledevelopment/sustainable-development-goals/ (accessed on 15 May 2020).

UN. 2019a. Climate change and poverty: report of the Special Rapporteur on Extreme Poverty and Human Rights Human Rights Council. Special Rapporteur on Extreme Poverty and Human Rights. Available online: https://digitallibrary.un.org/record/3802219?ln=en (accessed on 15 May 2020).

UN. 2019b. The Future Is Now. Science for Achieving Sustainable Development. Global Sustainable Development Report. Available online: https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf (accessed on 15 May 2020).

UNCCD. 2015. *Land Matters for Climate Reducing the Gap and Approaching the Target*. Bonn: UNCCD.

UNDP. 2020. Multistakeholder Collaboration for Systemic Change: A New Approach to Strengthening Farmer Support Systems. Available online: https://www.undp.org/content/undp/en/home/librarypage/environment-energy/multi-stakeholder-collaboration-for-systemic-change--a-new-appro.html (accessed on 15 May 2020).

WBCSD. 2015. CSA Initiative. Available online: https://www.wbcsd.org/Programs/Food-and-Nature/Food-Land-Use/Scaling-Positive-Agriculture/Resources/Climate-Smart-Agriculture-accelerating-progress-towards-the-Paris-Agreement (accessed on 15 May 2020).

WBCSD. 2017. Landscape Connectivity: A Call to Action. Available online: http://www.wbcsd.org/Projects/Climate-Smart-Agriculture/Resources/Landscape-Connectivity-A-call-to-action. (accessed on 15 May 2020).

WBCSD. 2020. *CSA Initiative. Smarter Metrics for Climate Change and Agriculture: Business Guidance for Target-Setting across Productivity, Resilience, and Mitigation*. Geneva: WBCSD.

WEF. 2016. *How Digital Is Solving 3 Problems in Agriculture*. Geneva: WEF.

World Bank. 2014a. *Turn down the Heat: Confronting the New Climate Normal*. Washington: World Bank.

World Bank. 2014b. *Increasing the Effectiveness of Multistakeholder Initiatives through Active Collaboration*. Washington: World Bank.

World Bank. 2015. *Resilient Supply Chains—Farmers & Food Industry Tackle the Shared Challenge of Climate Change—A Strategic Dialogue*. Washington: World Bank.

World Bank. 2020. *Harvesting Prosperity: Technology and Productivity Growth in Agriculture*. Washington: World Bank.

WRI. 2005. *Millennium Ecosystem Assessment, Ecosystems and Human Well-Being: Biodiversity Synthesis*. Washington: Island Press.

WRI. 2015. Global Multistakeholder Partnerships: Scaling up Public-Private Collective Impact for the SDGs. Available online: https://sustainabledevelopment.un.org/content/documents/1738Global%20Multistakeholder.pdf (accessed on 15 May 2020).
WRI. 2018. *Transforming Agriculture for Climate Resilience: A Framework for Systemic Change*. Washington: WRI.