Methods Proposed to Evaluate the Potential Impact of Climate Change on Food and Nutrition Security in Central America and the Dominican Republic

Working Paper No. 196

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Laura Cramer
Sophia Huyer
Angela Lavado
Ana María Loboguerrero
Deissy Martínez-Barón
Mary Nyasimi
Timothy Thomas
Philip Thornton
Jacob van Etten
Mark van Wijk

CGIAR

RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

CCAFS

Working Paper

Methods Proposed to Evaluate the Potential Impact of Climate Change on Food and Nutrition Security in Central America and the Dominican Republic

CGIAR Research Program on Climate Change,
Agriculture and Food Security (CCAFS)

Authors:
Laura Cramer
Sophia Huyer
Angela Lavado
Ana María Loboguerrero
Deissy Martínez-Barón
Mary Nyasimi
Timothy Thomas
Philip Thornton
Jacob van Etten
Mark van Wijk

Correct citation:
Cramer L, Huyer S, Lavado A, Loboguerrero AM, Martínez-Barón D, Nyasimi M, Thomas T, Thornton P, van Etten J, van Wijk M. 2017. Methods Proposed to Evaluate the Potential Impact of Climate Change on Food and Nutrition Security in Central America and the Dominican Republic. CCAFS Working Paper no. 196. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic partnership of CGIAR and Future Earth, led by the International Center for Tropical Agriculture (CIAT). The Program is carried out with funding by CGIAR Fund Donors, Australia (ACIAR), Ireland (Irish Aid), Netherlands (Ministry of Foreign Affairs), New Zealand Ministry of Foreign Affairs & Trade; Switzerland (SDC); Thailand; The UK Government (UK Aid); USA (USAID); The European Union (EU); and with technical support from The International Fund for Agricultural Development (IFAD).

Contact:
CCAFS Program Management Unit, Wageningen University & Research, Lumen building, Droevendaalsesteeg 3a, 6708 PB Wageningen, The Netherlands. Email: ccafs@cgiar.org

Photos: Neil Palmer (CIAT), JL Urrea (CCAFS)

Table of contents

Table of figures

Executive Sumary

In recent decades, food and nutrition security in Latin America and the Caribbean has strengthened, decreasing the number of the population affected by hunger from 14.7% in 1990 to 5.5% in 2014 (FAOSTAT, 2016), meeting the hunger goal of the Millennium Development Goals. However, climate change, extreme events, and climate variability threaten food and nutrition security, affecting food system activities all along the chain, from production, to processing and packaging, to distributing and retailing, to consuming. These changes in the food system activities in turn result in consequences for food system outcomes. This involves all aspects of food security: availability, access, utilization, and stability. The changes caused by climate change within the food system will affect nutrition security as well, through reduced dietary intake, undernutrition, increased disease outbreak and other issues. The food system activities, in turn, also affect climate change through greenhouse gas emissions, and could help mitigate climate change through changes in agricultural practices, reduced emissions from food transport, among others. The future challenge of food and nutrition security is to address these effects from all components of the food system and the existing interlinkages generated by climate change.

The knowledge of the multiple interactions between climate change and food and nutrition security will allow the region to formulate efficient programs and public policies focused on continuing to meet the millennium goals. While no broadly accepted and comprehensive analytical frameworks exist currently for assessing the impacts of climate change on food and nutrition security, this document proposes a framework under review and offers a number of recommended methodologies and tools to measure how the climate change and food and nutrition security affect one another. These methodologies are mentioned below:

1. **Food and nutrition scenarios:** This tool combines socio-economic and climate scenarios for strategic policy planning and investment decisions. The methodology has been implemented at global, regional, national and sub-national levels in several regions around the world including Central and South America (Andean countries). The main steps of the process are the development of exploratory scenarios guided by the key actors, quantification of these exploratory scenarios through multiple models and the retrospective use of these scenarios to evaluate decision paths with different groups of users. This gives an overview of various possible scenarios, in order to improve the formulation of policies and strategies and the implementation of specific actions in areas related to the food and nutrition security of the rural population.
2. **Modelling of regional/national food systems:** Within the existing models, the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by the International Food Policy Research Institute (IFPRI) in 1990 is a modular model that integrates climate, hydrological, crop simulation, value chain, soil use, nutrition, health and wellness analysis models, to support integrated analyses focused on identifying challenges and opportunities for food security, agriculture and natural

resources at global and regional levels. IMPACT has a "post-solution" module which provides recommendations regarding the projected scenarios, generating a robust analysis of interest to policy makers. In this way, IMPACT determines global and regional changes in agricultural productivity, economic dynamics of the sector and indicators of food security in conditions of climate change.

3. **Gender Toolbox:** In almost all societies, women play a key role in achieving household food and nutrition security. It is for this reason that understanding gender differences are essential to reduce the factors that generate food insecurity. The gender toolbox is useful to document the differential vulnerability of men and women to climate change and to identify gender-responsive interventions. It is designed to assess gender differences, establish a baseline analysis (what is known) and define ways in which gender is integrated right from project design, through implementation, monitoring and final evaluation.
4. **Surveys and databases as tools to understand and monitor the state of the agricultural sector:** In this case, two tools are proposed, the first is the Rural Household Multiple Indicator Survey (RHoMIS), which quickly characterizes a set of standardized indicators that comprehensively cover the whole food system (yield, food security, nutrition, trade, etc.). The second tool proposed is the Integrated Modelling Platform for Mixed Animal Crop systems (IMPACTlite), which allows the capture of information on different agricultural activities and characterizes the main agricultural production systems, contributing to the monitoring of programs or interventions on food and nutrition security issues.
5. **Climate-Smart Villages:** The purpose of Climate-Smart Villages is to help close the evidence gaps through participatory research with multi-stakeholder platforms, with smallholders as their fundamental axis, and their challenges both in terms of the climate-agriculture relationship and those related to rural development. Climate-Smart Villages are the ideal space to reflect and act on the dynamics that affect food and nutrition security in a context of climate change and variability.

In this sense, the previous methodologies inform stakeholders involved in the formulation of public policy on food and nutritional security on the main factors involved in the dynamics of the food system (climate change) and how they interact to guarantee access, availability and quality of food to the population. More and better public policies formulated based on reliable scientific information to deal with the impacts of climate change are needed to avoid endangering the achievements on food and nutritional security achieved recently.

Introduction

Climate change is predicted to have profound effects on the global food system in the coming decades. A recent meta-analysis of future impacts of climate change indicates that 70% of studies project declines in crop yields by the 2030s, with yield losses of 10-50% in half of the studies (Challinor et al., 2014). Incremental adaptation options such as changes in crop varieties and crop management regimes can reduce, but not eliminate, losses. Climate extremes, which may exceed critical thresholds for agricultural production, will increasingly require effective mechanisms to mitigate risk (IPCC 2012; Cai et al., 2014; Thornton et al., 2014). In the future, both incremental and transformative adaptation options must come into play. Transformative changes might include shifts away from certain crop-livestock systems, some farming households moving out of agriculture, or significant changes in diets (Vermeulen et al., 2013; Rippke et al., 2016). Similarly, incremental actions, such as sustainable intensification to achieve emissions efficiencies, will be necessary yet insufficient to achieve the mitigation targets suggested for developing country agriculture (Scholes et al., 2014; Wollenberg et al., 2015). Food systems will need to be transformed to better manage waste and respond to shifts in dietary patterns (Smith et al., 2013).

The future food and nutrition security challenge is framed by rapid change in smallholder farming and food systems. In some places, rapid urbanization may reduce the importance of smallholder agricultural incomes in achieving food security. But rural development is likely to be geographically uneven (World Bank, 2009), and farming in 2030 is likely to be characterized by a higher degree of inequality in farm incomes, sizes, technologies and market linkages. As such, different development pathways will need to be considered, some of which will necessarily go beyond smallholder agriculture sectors. Appropriate options may lie in the realms of food system functions including governance, diets and nutrition; options and financial innovation in support of transformative adaptation; supply chain governance and food loss and waste; food security safety nets; and closing gender gaps in assets and decision-making.

The purpose of this report is to examine the interconnectedness between climate change and food and nutrition security in Latin America and to offer a suite of methods for measuring how they affect one another. This first part of the report offers a brief overview of food and nutrition security in Latin America as related to the current and likely future impacts of climate change. The second part presents methods and tools recommended by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) for measuring the impacts of climate change on food and nutrition security.

Food and Nutritional Security in Latin America and the Caribbean

In the last decades, the prevalence of undernourishment in Latin America and the Caribbean (LAC) has dropped from 14.7% of the population undernourished in 1991 to 5.5% in 2015 (FAOSTAT, 2016), fulfilling the Millennium Development Goal (MDG) of reducing hunger. Additionally, the poverty rate has declined since 2002, from 44% to 28%. Despite the achievements, currently 34 million people in Latin America and the Caribbean are affected by hunger, and for this reason it is necessary to continue working toward eradication of this problem (FAO, 2015).

Food and nutrition security can be broken down into the components of availability of food, access to food, utilization of food, and stability of supply. In terms of availability, the region is characterized by having a caloric availability of 3000 calories per person per day, which has increased by 13% over the past two decades. Likewise, the region has enough food to feed its population and even export food to other parts of the world. The agricultural sector contributes 5% of the GDP, 23% of exports and 16% of the, labor supply in the region (CEPAL et al., 2016). Latin America and the Caribbean have a very heterogeneous agriculture, where 80% of the agricultural area corresponds to small-scale farming. Small farms generate 67% of the total production and 77% employment in the sector. Family farming is considered one of the pillars of food and nutrition security, poverty reduction and environmental sustainability (FAO, 2015). Latin America and the Caribbean provide great contributions to the world production of coffee (58%), soybeans (52%), sugar (29%), beef (26%), poultry (22%) and maize (13%) (FAO, 2015). Despite the high food availability in the region, there are differences in the concentration of food between the countries. For example, Argentina and Brazil provide 80% of grain production, followed by Mexico, while sugar production is led by Brazil and the production of meat and milk is led by Argentina and Brazil (FAO, 2011). Additionally, the yields in the region are lower compared to some other regions. This indicates that agriculture must grow, and this depends largely on investments that countries make in technology, infrastructure and resources (FAO, 2015).

In terms of access to food, the economy of the region has shown growth in recent years above the world average, due to increased employment opportunities mainly in the service sector. This has contributed to improving incomes of the population, which leads to improvements in access to food and reductions in hunger. However, the population in extreme poverty in the past two years increased from 66 million to 71 million (FAO, 2015). Despite economic growth in the region, it is important to consider that the distribution of income in Latin America and the Caribbean is considerably uneven. Also, the region has the highest average level of inequality in access to food (Leon et al, 2004), and about 12% of the population does not have the necessary income to meet their minimum nutritional requirements (Martinez & Palma, 2014). In addition to this, economic access to food is impacted by price inflation, affecting the ability of vulnerable families to afford healthy foods (Martinez & Palma, 2014).

Food utilization in Latin America and the Caribbean presents a challenge from both sides of the equation: overnutrition and undernutrition. This double burden of malnutrition is not unique to the region, as many developing countries are facing similar problems. According to FAO (2015), the situation of chronic undernutrition in Latin America and the Caribbean has decreased over the last 25 years, with chronic child undernutrition decreasing by 13% , data that are aligned with global trends. In terms of overnutrition, obesity also represents a health problem for the region. About 7% of children are overweight, exceeding the world average, and this is due to sedentary lifestyles and diets with high caloric intake and poor nutritional quality, which prevail in the region (FAO, 2015). In addition to this, the population of the region has other diseases generated by nutrient deficiencies, especially diseases such as anemia, which affects 44% of children and 22% of women (FAO, 2015).

Overview of Climate Change in Latin America and the Caribbean

Significant trends in precipitation and temperature have been observed in Central America (decreasing) and South America (increasing), and changes in climate variability and in extreme events have severely affected the region. Warming and increases in temperature extremes have been identified in Central America and most of tropical and subtropical South America (Magrin et al., 2014). Among the evidence of climate change in the region, a warming between 0.7 and 1 °C since 1970 has been identified, along with an increase in extreme temperatures in Central America and in the tropical area of South America, except along the Chilean coast where a cooling of -1 °C was recorded. Meanwhile, there has been an increase in annual precipitation in southeastern South America, producing landslides and flooding, and reduced precipitation in Central America and southern Chile (IPCC, 2014). In addition, extreme climate events in Latin America and the Caribbean have increased significantly, as in the case of an increasing number of storms in the last decade compared to the years 1970 to 1979. This has led to increased flooding in the region. In addition to the increase in storms in the last decade, events such as forest fires, droughts, floods and extreme temperatures affected about 40 million people, compared with the decade of the 1970s in which these events affected 5 million people. The costs associated with damage generated in the last 10 years for extreme climate events amounted to 40,000 million dollars (CEPAL et al., 2016).

Climate projections suggest that these trends may continue to 2100. Changes in streamflow and water availability have been observed and are projected to continue in the future, affecting already vulnerable regions. Other expected changes in the future are increased temperatures in the region, changes in rainfall patterns, decreased glaciers (in Andean countries), increases in sea level and changes in patterns of extreme weather events (Caribbean, Central America and the tropics) (Necco, 2012). By 2100, an increase in temperature between +1.6°C and +4°C in Central America and an increase of +1.7°C and +6.7°C in South America is expected under a medium and high emissions scenario (RCP 4.5 and 8.5), meanwhile the temperature rise considering a low emission scenario (RCP 2.6) range from +1°C and +1.5°C throughout the region (IPCC, 2014). The precipitation projections for the region indicate increases and decreases in the different geographical areas: Central America is expected to experience a variation of precipitation between -22% and +7%, to the northeast of Brazil the projections show a decrease of -22% of the precipitation, while southeastern South America can expect an increase of +25% and to the east of the Andes is expected an increase of drought periods (IPCC, 2014).

Climate change and agriculture

Increases in temperature and changes in precipitation and extreme climate events will affect differently the agricultural sector of the subregions in Latin America and the Caribbean. It is generally expected that in southeastern South America the productivity will be sustained or even increase until mid-century. However, it is expected that by 2030 the productivity in Central America, northeastern Brazil and parts of the Andean region will decrease, affecting the food security of the population, including the poorest (CDKN, 2014). In the case of Central America and the Caribbean it is expected that crops affected by climate change will be sugarcane, cassava, maize, beans, rice and wheat; in the Andean region impacts are expected on crops such as palm, soybeans, sugar cane, cassava, potatoes, maize, barley, rice and wheat, while Brazil will present changes in soybean crops, sugar cane, cassava, maize, rice and wheat. For the specific case of sugarcane in Central America and the Caribbean, an increase in production of between 5% and 25% is projected. In contrast, a reduction in the production of maize and cassava in Brazil, as well as a variation in Central America and the Andean region, are estimated (Samaniego, 2009).

Additional studies show a predicted reduction in yield of wheat and barley by 20% and a decline in maize production in Honduras, Guatemala and Panama between 21 and 34%, along with a projected reduction in beans yields by 66% in Guatemala. It is estimated that the projected reductions in crop yields in Latin America and the Caribbean will reduce the annual agricultural exports to US$50 billion in 2050 (Vergara et al., 2014). In addition, changes in crop yields in the region because of climate change, an increase of crop pests and diseases is also expected, along with decreasing availability of water for food production and other uses, mainly in semi-arid areas and the Andean region. Similarly, the capacity of livestock farming in the Andean region is expected to decrease, affecting the economy and food security of people whose livelihoods depend on livestock (CEPAL et al., 2016).

The negative impacts of climate change are exacerbated by land use change. Conversion of natural ecosystems is the main cause of biodiversity and ecosystem loss in the region, and is an important driver of anthropogenic climate change. Although Latin America and the Caribbean contribute relatively low emissions of greenhouse gases compared to industrialized countries, the region is highly vulnerable to climate change impacts due to its high economic dependence on agriculture, low adaptive capacity and the geographical location of some countries (CEPAL et al., 2016). Climate change will modify the agricultural production in the region, changing the suitability of areas to specific crops (unsuitable areas and new suitable areas), crop quality and yields. These effects will have an impact on economic growth in complex ways, via changes in prices, supply chains, and political relations (CDKN, 2014). Climate change will thus affect the entire production chain from the small-scale farmer (the most affected) to large agribusinesses, becoming a threat to food and nutritional security in the region (Vergara et al., 2014; Krishnamurthy et al., nd).

Risk to food and nutrition security in Latin America and the Caribbean

Although Latin America and the Caribbean is a vast region of fertile land, has sufficient availability of food for its population, and has achieved the MDG of reducing hunger, food security and nutrition are harmed by factors such as the crisis of the global economy, rising food prices due to the opening of new markets focused on basic commodities such as maize, growth of biofuels, the occurrence of natural disasters, and climate change (Martinez & Palma, 2014). In recent decades, climate change and climate phenomena faced by the region have led to the loss of large volumes of food production, as in the case of the drought in 2001, which generated losses of 18% of total production and decreased household income and labor supply (Leon et al., 2004). According to FAO data, agriculture is the sector most affected by climate change in the region, and will have major impacts in countries facing major problems in food security, such as Bolivia, Ecuador, El Salvador, Honduras, Nicaragua and Paraguay (CEPAL et al, 2016). Consumption of cereals such as rice and maize exceed production, increasing countries' vulnerability to price increases of these products. In addition, the countries of Central America are particularly vulnerable to losses in agricultural production from tropical storms, and few countries have either the capacity or the long-term mechanisms in place needed to reduce vulnerability (FAO, 2011).

Socioeconomic conditions have improved in Central and South America in recent years; however, high and persistent levels of poverty exist in most countries resulting in high vulnerability and increasing risk to climate variability and change. Changes in agricultural productivity with consequences for food security associated with climate change are expected to exhibit large spatial variability. Beyond the impacts of climate change on food security are direct effects on nutrition, due to the change in food composition and effects on livelihood options concerning employment and food cost. Therefore, the population in poverty will be most affected by food insecurity caused by climate change (HLPE, 2012; Mogelgaard et al., 2015). It is expected that the population at risk of hunger could be 85 million in 2080 and will present 1.4 million of new cases of child malnutrition in 2050 due to climate change in the region (Samaniego, 2009). Changes in weather and climatic patterns are negatively affecting human health in the region, both by increasing morbidity, mortality, and disabilities, and through the emergence of diseases in previously non-endemic areas.

Linkages between Food and Nutrition Security, Poverty and Climate Change

The links between improved food and nutrition security and poverty reduction, through increased productivity, capacity to participate in the economy, and cognitive development, for example, are widely recognised (World Bank, 2006; IFPRI, 2015). Nutrition has been highlighted as one of the top investment priorities for global development, given its high economic returns (World Bank, 2006). At the same time, there is strong evidence that poverty reduction is a key strategy for improving nutrition (Headey, 2013). This “virtuous cycle” (IFPRI, 2015) is seen as an essential input to, and outcome of, sustainable development. The current and future impacts of climate change in the region, however, will affect the food system through multiple avenues and place strains on the food and nutrition security of the population.

Currently no broadly accepted and comprehensive analytical frameworks exist for assessing the impacts of climate change on food and nutrition security. One framework under review by CCAFS is shown in Figure 1 (adapted from Tirado et al., 2015 and Eriksen, 2007). There are others that can equally well be used (see, for example, Thomson and Fanzo, 2015). A useful framework needs to be able to include the multiple interactions between climate change and food and nutrition security in a comprehensive manner. In addition, it needs to be linked to an appropriate set of nutrition-related indicators to allow for monitoring and evaluation.

The framework in Figure 1 starts from the basis that climate extremes, variability and change affect food system activities all along the chain, from production, to processing and packaging, to distributing and retailing, to consuming. These impacts are mediated by the potential resources available to countries, communities, households, and individuals, along with the economic and political contexts, and the formal and informal policies and institutions in place that either boost adaptive capacity and offer a measure of protection or perpetuate inequity. The framework also acknowledges that shocks, trends, and seasonality affect undernutrition and its causal pathways. Climate variability and change similarly influence shocks, trends, and seasonality observed in many developing countries, and these represent further stressors in the lives and livelihoods of exposed communities (Tirado et al., 2015).

The impacts of climate extremes, variability and change on food production will come as a result of increasing temperatures and changes in precipitation and more frequent climate events such as flooding, and they will be compounded by accompanying changes in plant and animal pests and diseases. Effects in processing and packaging may primarily be experienced by smallscale farmers who will face challenges in postharvest storage and losses as a result of changing weather patterns and increased pests. Agribusinesses might also need to adapt transportation and processing systems to cope with increased temperatures and quicker spoilage. Distributing and retailing sectors are reliant upon infrastructure that is vulnerable to damage by climate extremes, for example storms which shut down air and sea ports or wash out roads. Consumers can be affected by price increases that result from decreases in production or interruptions in the other activities along the chain. The food system activities, in turn, also affect climate change through greenhouse gas emissions, and could help mitigate climate change through changes in agricultural practices, reduced emissions from food transport, among others.

These changes in the food system activities in turn result in consequences for food system outcomes. This involves all aspects of food security: availability, access, utilization, and stability. As mentioned in the above section on the impacts of climate change on agriculture, yields are predicted to decline for many crops due to temperature increases and changes in precipitation. The effects will be felt outside of just the availability component, however. Access could decline for farm households who have subsequent declines in income. Price increases could hurt the urban poor by requiring them to spend a greater share of income on food. Utilization might be affected through reduced nutritional value of food in the market, lower dietary diversity, and concerns about food safety. Stability of food security could be reduced by the multiple impacts of climate, including longer dry seasons and potential for transportation disruptions.

The changes caused by climate change within the food system will affect nutrition security as well. Reduced dietary intake, undernutrition, and disease are all interlinked within themselves and to food security. The short-term consequences include increased mortality, morbidity and disability, while the longer-term consequences include reduced intellectual ability, economic productivity, and metabolic and cardiovascular diseases (Tirado et al., 2015).

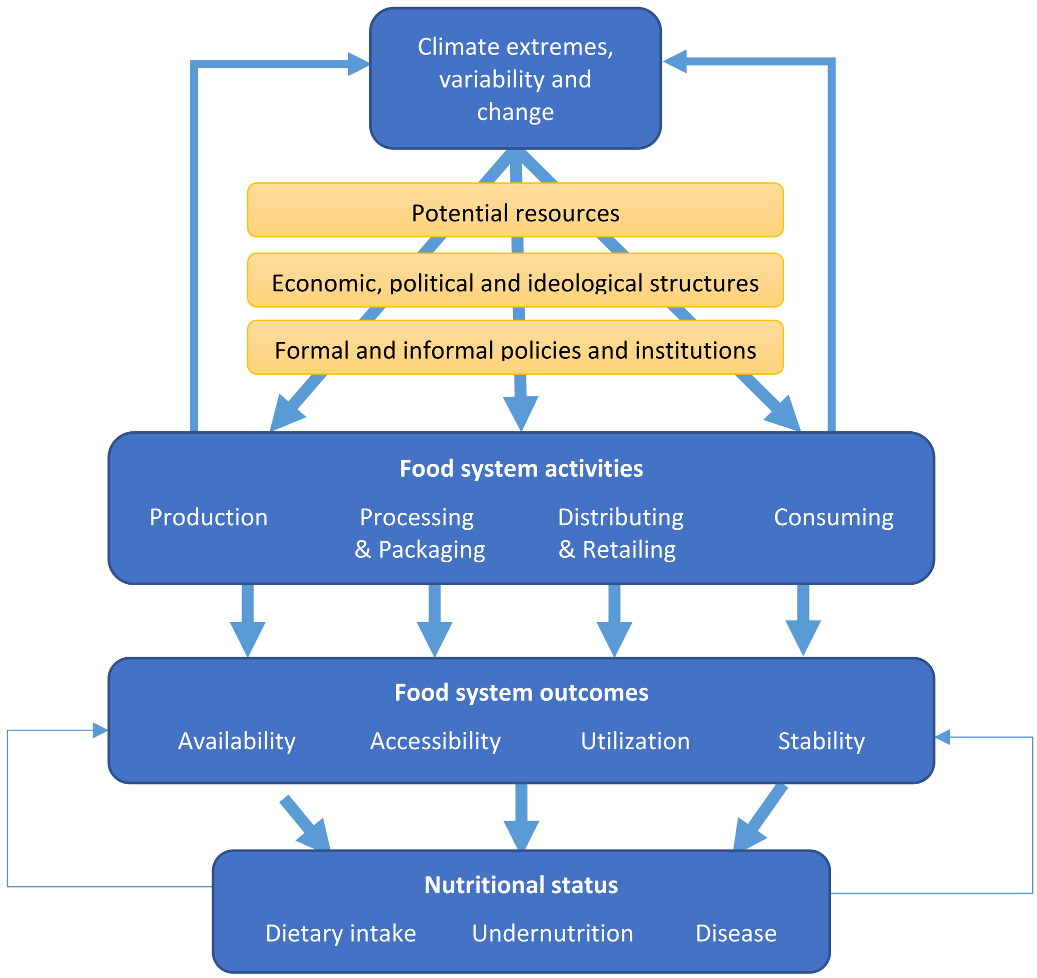

Figure 1. Climate change impacts on the food system and nutrition

Toward metrics of food and nutrition security

The CGIAR Strategy and Results Framework (CGIAR, 2015) is based on a vision of a global food system that is more productive, carbon neutral and provides nutritious options at affordable prices. Three high-level targets, aligned with the Sustainable Development Goals, indicate the domains of intervention of public and private development donors and investors in the broader field of agricultural research for reducing poverty, improving food and nutrition security for health, and improving natural resources systems and ecosystems services. For the second of these, four targets have been defined for 2022 (targets for 2030 in parentheses):

1. Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year (<2 to 2.5% per year).

2. 30 million (150 million) more people, of which 50% are women, meeting minimum dietary energy requirements.

3. 150 million (500 million) more people, of which 50% are women, without deficiencies of one or more of the following essential micronutrients: iron, zinc, iodine, vitamin A, folate, vitamin B12.

4. 10% reduction (33% reduction) in women of reproductive age who are consuming less than the adequate number of food groups.

CGIAR and its international and national partners are all working towards these targets, albeit in different ways and different contexts. CCAFS, for example, is contributing to improving the diets of poor and vulnerable people, which in turn contributes to targets 2 and 3 above, by working with organisations at multiple scales that design and enact plans and increase investment toward improved access to diverse and locally acceptable diets. In relation to the logistics of collecting appropriate indicators for tracking progress towards high-level outcomes, many of these indicators are already being collected on a regular basis at national level by different organisations and funding agencies. Projects and programs can make considerable efficiency gains by linking into such indicators, where necessary supported by other quantitative and qualitative evidence of contribution. Some examples would include average dietary supply adequacy (%), collected in FAOSTAT databases; rates of child stunting, collected in annual UNDP Human Development Report statistics; and proportions of population with shortfalls of key vitamins and minerals, collected as part of future SDG monitoring work (SDSN, 2015), for example.

Harnessing Knowledge to Inform and Improve Policies

As the sections above make clear, public policy will increasingly need to address the impacts of climate change, if achievements to date in food and nutrition security are not to be compromised. These achievements are considerable: the countries of Latin American and Caribbean have halved the number of hungry people (in compliance with the MDGs), even as the effects of climate change have started to manifest themselves. These achievements have been facilitated by the formulation and implementation of food and nutrition security policies in seven countries, and the development of policies, plans and strategies for food security in 20 countries in the region. The pioneering initiative “Latin America and the Caribbean without Hunger 2025” was launched in 2005, with the goal of eradicating hunger by 2025. Early in 2015, the countries of the region signed the Plan for Food Security, Nutrition and Hunger Eradication of CELAC 2025, which *"encourages countries of Latin America and the Caribbean to redouble efforts to identify the key areas of policy to accelerate and consolidate the process of eradication of hunger and face the double burden of malnutrition in the region, where overweight and obesity are increasingly complemented this scourge"*. The plan recognizes climate change as a major challenge to food and nutritional security at the regional level (CEPAL et al., 2016). Support for investment will be needed in infrastructure, human capital and agricultural technologies that enable farmers to improve their responsiveness. To date, investment in climate adaptation plans has been less than investment in the development of contingency measures (Falconi et al., 2012), despite the many adaptation measures that exist in the agricultural sector (Samaniego, 2009).

One of the hypotheses underlying CCAFS’s research agenda is that improving enabling policy environments and catalyzing the increase of targeted investments across scales can lead to improvements in food security in a changing climate. For this to happen, engagement with stakeholders is critical: global actors directing finance to developing countries and national governments investing to help overcome constraints to scaling. As noted above, ample evidence exists of the links between improved nutrition and poverty reduction via increased productivity, capacity to participate in the economy, and cognitive development (World Bank 2006; IFPRI 2015). Achieving food security is recognized as a parallel process with development and poverty reduction (Misselhorn et al., 2012). National policies are key, but engagement needs to happen with civil society, the private sector, and other actors at multiple levels. Evidence for successful engagement with stakeholders leading to policy revision comes from recent CCAFS work with scenarios (CCAFS 2015; Vervoort et al., 2014).

Sustained and direct engagement between scientists and decision makers can help to create enabling policy environments. CCAFS and partners are undertaking research on existing science-policy platforms, which can help to bring research results into decision-making spheres. Such work can include robust analyses of the likely impacts of climate change on food security, “good enough” governance mechanisms (standards of governance that are adequate, rather than optimal, for specific outcomes; Grindle 2007; Purdon 2014) to support scaling up different interventions, and priority setting for investment decisions via multi-dimensional scenarios.

Tailored communications tools and approaches can also be used for engaging and informing next users: learning events such as webinars, personal briefings with policy makers, media outreach at the national and global level to share critical results, and developing engaging training materials relevant to partners' needs.

In almost all societies, women play a key role in achieving household food and nutrition security. Women need to be supported in adopting appropriate interventions at the local level, and where possible through policy processes that govern ownership and control over assets such as land and agricultural inputs. Gender transformative approaches can be used, for example within scenarios engagement activities, to attempt to alter (at least to highlight the issues surrounding) the balance of power and empowerment of women - there is evidence that shifting control over productive resources to women can improve food security (Sraboni et al., 2014).

One of the ways in which CCAFS is working to highlight the need for gender transformative approaches is through national and local learning alliances. These platforms bridge the science-policy divide with a goal of creating evidence-informed decision making. Another benefit to these platforms is the creation of spaces for sharing local priorities and needs with national level decision makers. This incorporation of local level perspectives in policy creation at higher levels can help formulate policies that are better attuned to local needs and priorities.

CCAFS and partners are also tackling priority setting by working with a wide variety of ex-ante methods linked at multiple scales, utilizing enhanced crop, livestock, agricultural system, agricultural sector, economy-wide and household models that can evaluate land-use change, environmental impacts and socioeconomic drivers of food security under a changing climate, from global level to the field and household level. At global and regional scales, these models include the IMPACT model from the International Food Policy Research Institute (for an application of the model, see Rosegrant et al., 2009, for example); GLOBIOM, developed at the International Institute for Applied Systems Analysis (IIASA) (for an application of this model, see Havlik et al., 2014, for example); and MAGNET, developed at Wageningen Economic Research (formerly LEI WUR) (Woltjer et al., 2014). Complementary tools at different scales are being developed for evaluating the trade-offs and synergies in food systems based on data reduction techniques and novel global and regional datasets. These quantitative methods are being combined with cutting-edge participatory scenarios approaches to address food security at national and subnational levels. These tools make it possible to carry out detailed exploration of food security in different situations, with a focus on food and nutrition security, poverty, and diversity in household choices in consumption and production. The modelling of multidimensional food system outcomes still needs data and model improvement (Rutten, 2013). More work is also required on understanding better the similarities and differences between different economic models (Nelson et al., 2014). Nevertheless, the modelling of food systems and their nutritional and health impacts is developing rapidly (Springmann et al., 2016), and this work will become increasingly important in addressing issues around food and nutrition security. When linked with participatory scenarios processes, this work allows variously for strong collaboration with the private sector, the inclusion of the perspectives of women and young people, and the incorporation of local needs, in helping to guide policy processes.

CCAFS areas of expertise

CCAFS is made up of the 15 international agricultural research centres of CGIAR, integrating thematic work across multiple global, regional and local partners. The goal of CCAFS is to overcome the additional threats posed by a changing climate to achieving food security, enhancing livelihoods and improving environmental management. The program works to identify and test pro-poor adaptation and mitigation practices, technologies and policies for food systems, adaptive capacity and rural livelihoods, and to provide diagnosis and analysis that will ensure cost-effective investments, the inclusion of agriculture in climate change policies, and the inclusion of climate issues in agricultural policies, from the sub-national to the global level in ways that bring benefits to the rural poor (Vermeulen et al., 2012).

CCAFS works on research activities clustered into four thematic areas: priorities and policies for Climate-Smart Agriculture (CSA); climate-smart technologies and practices; low emissions development; and climate services and safety nets. Research is carried out at the global level and in five regions: East Africa, West Africa, South Asia, Southeast Asia and Latin America. The CSA concept is used to structure CCAFS's approach to climate-responsive options, given that many proposed actions in agriculture deliver on both adaptation and mitigation. CSA is defined as agriculture that (a) sustainably increases agricultural productivity and incomes, (b) adapts and builds resilience to climate change, and (c) reduces and/or removes GHG emissions where possible (Lipper et al., 2014). The relative importance of outcomes for food security, adaptation and mitigation varies across locations and situations, as do potential synergies and trade-offs between objectives (Lipper et al., 2014), providing a challenge for prioritising investments. The concept extends beyond on-farm practices to include landscape-level interventions (e.g. management of farm-forest boundaries), services (particularly information and finance), institutions (particularly market governance, incentives for adoption) and the food system (particularly consumption patterns and wider climate-informed safety nets).

CCAFS and partners have a wide range of skills and expertise to deliver on this agenda. "Priorities and Policies for CSA" works to improve evidence and tools on enabling policy environments and priority-setting for targeted investment to support the scaling of climate- and nutrition-smart agricultural technologies, ultimately to contribute to food and nutritional security under climate change. "Climate-Smart Technologies and Practices" provides the evidence on the synergies and trade-offs among technologies and practices, towards the achievement of CSA outcomes and impacts across a range of agro-ecologies and social contexts. "Low Emissions Development" tests the feasibility of reducing agricultural GHG emissions intensities at large scales while ensuring rural food and nutrition security in low-income and middle-income countries. "Climate Services and Safety Nets" addresses critical gaps in knowledge, methodology, evidence, and capacity needed to effectively implement a set of scalable interventions that use climate-related information to manage climate-related risk.

Participatory research is carried out at sites ranging from village to district scale at which portfolios of interventions are tested in a globally comparable manner with farmers, development agencies and the private sector. Such activities are linked to higher-level analyses such as models of scaling processes, food systems and trade-offs to generate information relevant to societal questions on alternatives for agricultural development.

CCAFS, CGIAR and partners deliver on science quality in several areas: ex-ante evaluation of climate- and nutrition-smart options at multiple scales; participatory evaluation of climate-smart portfolios; identifying priorities and options for low-emissions development; weather-related agricultural insurance products and programs; and research on gender and social integration under climate change. CCAFS and partners also have expertise on delivering outcomes, being an effective knowledge partner in CSA implementation via a wide range of global, regional and national partnerships, and in other global communities such as Future Earth.

Methodologies Proposed

The proposed methodologies for analyzing the impacts of climate change and climate variability on the different dimensions of food and nutrition security are described below.

Methodology 1: Food and nutrition scenarios

1. Description of the Methodology

1.1. Literature review of the methodology

The public policy formulation process and decision-making are challenges since they must consider many interrelated variables in the search for the common good, and on issues such as food security, the process goes beyond scales and various time periods. According to Laborde et al. (2013), the understanding the dynamics of food and nutrition security must consider many uncertain drivers operating at household level (such as income and education), at the national level (such as agricultural and social protection policies), and globally (such as climate change and trade policy).

Several studies exist that project future food demand (Alexandra and Bruinsma, 2012), its prices and malnutrition rates (Dijk van and Meijerink, 2014). The results are diverse, and thus it is difficult to generate comparisons because there are differences in scenario assumptions, indicator design, and reporting of results (van Dijk et al., 2015). The findings present the need to increase food production by 60% by 2050 (Alexandra and Bruinsma, 2012) and oscillations of between 9% and 54% in maize, rice and wheat prices are projected (Dijk van And Meijerink, 2014).

However, rather than determining the most accurate projections, the actors involved in public policy formulation processes for food and nutrition security need to know what the main factors are that influence the dynamics and how they interact to guarantee access, availability and quality food to the population.

There are different methodologies to develop projections and future scenarios that involve food and nutrition security in a context of climate change and socioeconomic dynamics. CCAFS has developed and implemented a tool that combines socioeconomic and climate scenarios for strategic policy planning and investment decisions. The method has been implemented at the global, regional, national and sub-national level in developing countries. These countries not only must ensure their development, but also must systematically address the challenges to sustainable food security, considering their unique systems (Ericksen et al., 2009; Vermeulen et al., 2013). The CCAFS methodology addresses these aspects.

1.2. Description of the methodology proposed

The main steps of the process are the development of exploratory scenarios guided by the key actors, the quantification of these exploratory scenarios through multiple models and the retrospective use of the scenarios to evaluate decision paths with different groups of users (Vervoort et al. 2014). Through workshops and close collaborations with policy makers, CCAFS has facilitated the adaptation and use of these scenarios, which help the different stakeholders to establish plans, policies, and more robust strategies and provide plausible options in the face of different possible futures.

The methodology of future scenarios includes the analysis of the challenges of the agrifood system through associated variables such as yield, production, and demand through plausible and diverse scenarios by key actors. In addition, the key factors identified as the main challenges about climate change, food security and environment are included in the analysis. These factors are characterized according to their state and are evaluated in their different combinations to identify how diverse and plausible they may be to consider their level of uncertainty.

The methodology combines qualitative and quantitative methods. First, the expertise of the key actors is considered to determine the main challenges and associated factors, then quantitative tools are used to develop the possible scenarios. Its recent application in the regions of South and Southeast Asia and Central and South America counted on the use of the OLDFAR model for the construction of diverse scenarios incorporating the possible compatible combinations between the factors according to their state. This software allows maximizing the diversity between the scenarios with a range of possibilities to be considered by the key actors (Palazzo et al., 2014). Additional factors may be included, such as high-low food availability, high-low access to biofortified varieties or high-low diversity of basic grains for regular consumption, combined with factors related to access and availability of water resources, governance, management of natural resources, among others.

Additionally, this methodology includes socioeconomic as well as climatic scenarios. The socioeconomic component includes variables such as population, gross domestic product, technological impacts on yields, input costs, prices, among others, which are incorporated in two agricultural economic models (partial equilibrium models): GLOBIOM developed by the International Institute For Applied Systems Analysis (IIASA) and IMPACT (Rosegrant et al., 2009), developed by the International Food Policy Research Institute (IFPRI). In addition, the scenarios are quantified using a land-use change model (LANDSHIFT, Schaldach et al., 2013) that simulates maps of land use change, ecosystem services and biodiversity (Palazzo et al., 2014).

2. Results/Outputs

Partial equilibrium models generate information useful for key stakeholders that goes beyond just regional scenarios. In this way, they offer inputs on how the region can be affected by forces outside its control such as global markets and climate change. These factors can have significant effects on regional dynamics. For example, the negative effects of climate change on rice yields are equivalent (in magnitude) to the positive effects of several of the regional scenarios. This suggests that some assumptions behind regional scenarios (such as high public and private investment in agriculture) are capable of neutralizing the negative effects of climate change. The models also highlight how the region will interact with the rest of the world in terms of trade and how countries in the region may become more or less vulnerable to shocks in global prices due to changes in import and export levels of agricultural products, which influences the availability of food (Palazzo et al., 2014).

The participatory approach of the methodology allows addressing a variety of actors directly or indirectly linked to the agricultural sector, such as environment, health, trade, energy, among others, and allows for joint interaction to address common futures, with systemic challenges that are equally relevant for each sector and at various levels. Likewise, the methodology serves as a complementary input that provides an overview of various possible scenarios to improve the formulation of policies, strategies, and implementation of specific actions, such as guaranteeing the food and nutrition security of the rural population.

3. Implementation cases

The implementation of this methodology has been carried out in several regions around the world, including Central America and South America (Andean countries). The process in the region began with the development of the scenarios for the countries of Central America and the Andean countries. The use of the methodology has served to strengthen and validate national policies on agriculture and climate change (Colombia, Peru, Ecuador, Bolivia) to facilitate the local contribution to the Climate Change Adaptation Strategy for the Agriculture Sector of Honduras and to support the formulation of the Costa Rica´s Intended Nationally Determined Contributions. The main results of the scenarios for Central America and the Andean countries are shown below, which can be found in more detail in Palazzo et al. (2014).

Main results of the scenarios in Central America

The main drivers identified in both regions (Central America and Andean countries) by the key players were the Gross Domestic Product, yields in crops and livestock, and production costs. In the case of Central America, key actors identified the most relevant and uncertain change factors that they believed could definitely transform or significantly affect agriculture and food security. The factors identified were institutional capacity, markets, wealth distribution, and water resources. The scenarios developed were named Crowded; Batkun: The Beginning of the Maya Prophecy; Libertarians Without Liberty; and The New Mayan Collapse (Figure 2).

Scenarios	Markets	State Institutional Capacity	Water Resources	Wealth distribution
Crowded	Participatory, not regulated	Unequal	High	Inequitable availability, driven
Batkun: The Beginning of the Maya Prophecy	Participatory, regulated	High	High	Inequitable availability, driven by the State
Libertarians Without Liberty	Participatory, not regulated	Low	Low	Inequitable availability, driven by the market
The New Mayan Collapse	Not participatory, not regulated	Unequal	Low	Inequitable availability, driven by the market

Figure 2. Central America's Scenarios by 2050 for each factor of change. Source: Palazzo et al. 2014.

In the scenarios, regional demand is increasing for agricultural and livestock products. The supply of these products was modeled using the GLOBIOM model for the 2000-2050 period, also considering the biophysical effects of climate change on agricultural production. Agricultural production has grown over the period analyzed in all scenarios, mainly due to the growing demand for livestock products from a growing population. As a result, there are production increases, although with important environmental implications in some of the scenarios.

Regarding food security, measured in available kilocalories per capita per day, has increased during the period analyzed. The available kilocalories per capita decrease in one of the scenarios by approximately 5-10% by 2050 compared to 2010 (Figure 3). Examining changes in food demand per capita allows for the understanding of the effect of the market situation and the effect of income on food consumption.

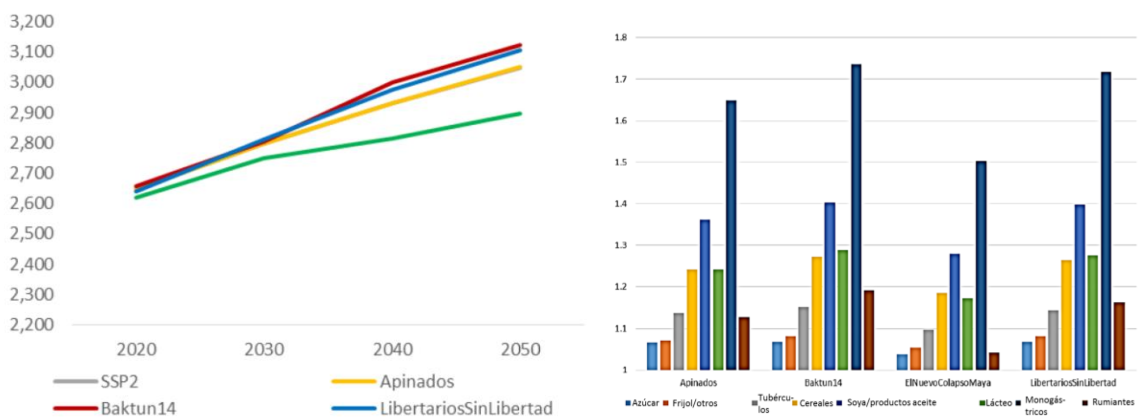

Figure 3. Available daily calories per capita and food demand per product indexed to 2010 per capita demand. .
Source: Palazzo et al. 2014.

The demand for monogastric species grows from 2010 to 2050 in all scenarios due to the expansion of the monogastric species production and the relative decrease of the meat prices of these species. However, compared with the demand for ruminant meat, one of the scenarios presents a much smaller increase due to the low GDP per capita growth and higher meat prices.

The development of scenarios is a tool by which the various policies related to climate change, agriculture and food security are reviewed, updated and strengthened. Analyzing the implications of the various scenarios can determine how robust the policy is to address the challenges associated with each scenario.

In the case of Honduras and Costa Rica, national scenarios were developed based on the work of scenarios carried out at the regional level. The above exemplifies one of the characteristics of this methodology represented by the ability to adapt and adjust to the different contexts, in order to be able to respond to the particular needs of each process.

Methodology 2: Modelling of regional/national food systems

1. *Description of the Methodology*

1.1. Literature review of the methodology

For more than 50 decades, different institutions around the world have focused on modeling and projecting food security through quantitative or qualitative models, based on projections of trends and models of global trade. However, the process of modeling future food security in an integrated way turns out to be complex. Given the above, the use of simulation models for the agricultural sciences proves to be very useful. Currently, the development of agricultural models has had great scientific advance and many models have included climate change within their processes (MacCalla and Revoredo, 2001). The projections of the effects of climate change on agricultural systems are a complex challenge, since it is necessary to include both physiological and climatic variables of the crop and underlying aspects related to the behavior of markets, ecosystems and population dynamics.

In this sense, there are two main types of analysis. The first of them is to use climate model data in a biophysical model (also called "crop model") to determine the direct climate impact on crop productivity. The second is to use some measure of climate impact on yield (often taken from the first step) in an economic model. Referring to the first type of analysis, there are studies such as those of Rosenzweig et al. (2014) and Müller and Robertson (2014). Likewise, the study conducted by Nelson et al. (2013) present a comparison of the results of several bioeconomic models (second type of analysis). Examples of uses of bioeconomic models in evaluating the impact of climate change on agricultural productivity, including some of the first models applied to climate change, are Nelson et al. 2013; Rosegrant, Agcaoili-Sombilla, and Perez 1995; Nelson et al. 2009; Nelson et al. 2010; Fischer, Shah, and Velthuizen 2002; Rosenzweig et al. 1993; and Rosenzweig and Parry 1994. Examples of the second type of analysis put together to analyze both the direct and indirect effects of climate change on agriculture - in addition to some of the analyses already cited for bioeconomic models - include Rosegrant et al. (2015); Hachigonta et al. (2013); Waithaka et al. (2013); Jalloh et al. (2013); and Thomas et al. (2013a, 2013b).

In this context, the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model developed by the International Food Policy Research Institute (IFPRI) in 1990 is a modular model that integrates climate, hydrological, crop simulation, value chain, soil use, nutrition, health and wellness analysis models, to support integrated analyses focused on identifying challenges and opportunities for food security, agriculture and natural resources at global and regional levels. The development of the IMPACT model was in response to the need to know projections related to poverty alleviation, rural development and food security. Since its inception, the model has been in a constant process of development and improvement, including the analysis of scenarios and integrating aspects such as climate change within the food system (Robinson et al., 2015).

One of the most recent improvements of the IMPACT model is the integration of aquaculture and water modules, which include models of demand dynamics and future water availability for the agricultural sector, such as hydrological models, watershed management models and models of water stress. More recently, new food security modules were included to identify changes in the number of malnourished children, as well as analysis of the effect of climate change on agriculture and its impacts on food security. Finally, models of agricultural land markets and land use have been added to identify land demand and future changes in greenhouse gas emissions as a consequence of land use change. Currently, the model has information available for 62 markets for agricultural products and 159 countries, with a projection period up to 2050 (Robinson et al., 2015).

The model is available in a web interface (beta version), which serves as a data visualization tool to facilitate and encourage the use IMPACT in policy analysis (Robinson et al., 2015).

1.2. Description of the methodology proposed

The IMPACT model consists of five interconnected components: i) climate models, ii) water models, iii) water demand, iv) crop modeling and v) multimarket modeling. The first of these provides climate information, which serves as input for crop and water modeling components. In this component, climatic data are available on a monthly basis, which allows the generation of daily climatic data for the conditions of the recent past (2005), as well as the future (2050). The second component integrates hydrological models such as the Global Hydrology Model (lGHM) that simulates rainfall and runoff processes, the IMPACT Water Simulation Model (IWSM) that models the operation of water reservoirs and water supply to economic sectors, including irrigation, and the Crop Water Allocation and Stress model (ICWASM), which allocates the net amount of irrigation water to crops and estimates the impact of water scarcity on yields (Robinson et al., 2015).

For its part, the third component estimates the demand for water for crops, industry, households and livestock. The demand for irrigation water is considered as the amount required by the crop, not satisfied by precipitation or soil moisture. The crop modeling component requires surface, yield and system type information (irrigation or rainfed) at a sub-national level called "food production units". This component allows the modeling of livestock production (number of animals, meat, dairy) and processed products (supply, input costs and prices), including the effects of climate change on crop yields and productivity through the DSSAT software (Robinson et al., 2015).

The IMPACT-Multimarket component includes information on macroeconomic trends (demographic and economic growth), value chains, land use, national and global markets (159 countries), and demand for agricultural products (food, biofuels, industrial). This component identifies how market changes (prices and incomes) affect food security, the potential effects on the number of malnourished children and the population at risk of hunger. Together with the hydrological models, this component allows for the evaluation of the effects of climatic and hydroclimatic variability on water and food systems, socioeconomic growth driven by the change in water demand and investment in water storage and irrigation infrastructure (Robinson et al., 2015).

In addition, IMPACT has a "post-solution" module which provides recommendations regarding the projected scenarios, generating a robust analysis of interest to policy makers.

To develop a food security analysis, the IMPACT model has two specific modules. The first one estimates changes in the number of undernourished children by considering variations in food availability at the national level. The second module estimates the changes in the population at risk of hunger, also based on variations in food availability. The results of these modules are included in the multimarket modeling component to be analyzed with socioeconomic information. It is important to remember that the latter includes hydrological modeling data, which in turn are based on climate simulations (Robinson et al., 2015).

In this sense, it is observed that food security is an aspect widely analyzed with the IMPACT model. This methodology allows analysts to examine the interaction between the production, demand and trade of agricultural products, considering the physiological aspects of the crop and the changing climatic conditions. In the same way, it allows for analyzing the implications of these changes and factors in human well-being, an important aspect to be considered in future scenarios for decision-making. In this way, the IMPACT model determines global and regional changes in agricultural productivity, in the economic dynamics of the sector and in food security indicators under conditions of climate change.

2. Results/Outputs

The IMPACT outputs generate information on harvested area, yield, production, quantity consumed, the quantity of feed for the consumption of livestock, the amount used for the production of biofuels, prices and net trade for each agricultural product, by country and year (until 2050).

Additionally, the IMPACT model generates analysis and tools that allow for the development of scenarios based on the internal logic of the model. The model also allows the quantification and simulation of scenarios for verification and adjustment. These models allow decision makers to assess robustness and test different policies against alternative scenarios. In addition, the model provides indicators of food security, such as the malnutrition rate in children, average calorie consumption, and population at risk of hunger, allowing governments to verify the status of compliance with the Millennium Development Goals (Robinson et al., 2015).

For purposes of this document, a sample of the results of the IMPACT model has been developed in Latin America and the Caribbean countries. For each country, temperature and precipitation changes were projected by four GCMs (general circulation models, which we also refer to simply as “climate models”) coming from the fifth assessment report (AR5) for the IPCC. Simply reviewing these is a helpful tool to see the magnitudes of the projected changes – which hint at the severity of the change for agriculture – and it helps in looking at the geographically heterogeneous effect of the projected changes, which point to potential problem areas (and potential areas of opportunity) within each country.

Additionally, the seven biophysical models of AgMIP GGCMI (Rosenzweig et al., 2014) were evaluated. However, according to Rosenzweig et al. (2014), three models that failed were discarded. Among the four remaining models, the median impact of climate change for each crop was calculated at each pixel (half degree gridcell) for each MCG.

Subsequently, in order for the pixel data to interact with the IMPACT model (Robinson et al., 2015) at the subnational level in FPUs ("food production units", which are the intersection of country boundaries and major river basins), the MapSPAM (You et al., 2014) was used to generate a gridded data on harvested area for each crop to aggregate the yield change data.

The IMPACT model also received assumptions about GDP and population growth from the SSP2 scenario from the IPCC's AR5 report. In addition, IMPACT makes assumptions about exogenous growth rates in agricultural production by crop and country, and also assumes elasticities for demand and supply response to prices, and in the case of demand, to income. Also, the IMPACT model solves for global prices that will equilibrate global supply and demand for each commodity it models for each year.

As a result, changes in the yield of selected crops in Latin America and the Caribbean by 2050 are shown below, under climatic change scenarios generated by the IMPACT model (Figure 4). While there is a decrease in the yield of some crops under climate change scenarios, there are also positive impacts that will increase crop yields in the future. In terms of food security indicators, the IMPACT model results present the change in the number of the population at risk of hunger under climate change conditions in the region for the same period (Figure 5). According to these data, it is identified that the exchange rate is higher in the face of less favorable climatic conditions and, on the contrary, the exchange rate indicates that there is a smaller population at risk of hunger when the climate projections consider less negative scenarios.

In general, the model's output data indicates that the number of crops that are adversely affected by climate change is greater; for this reason it is important to focus on promoting adaptation strategies, such as increased investment in agricultural research, identification of possible alternative crops to cultivate, prioritization of areas to focus research and extension efforts, and to a certain extent, suggestions for infrastructure improvement.

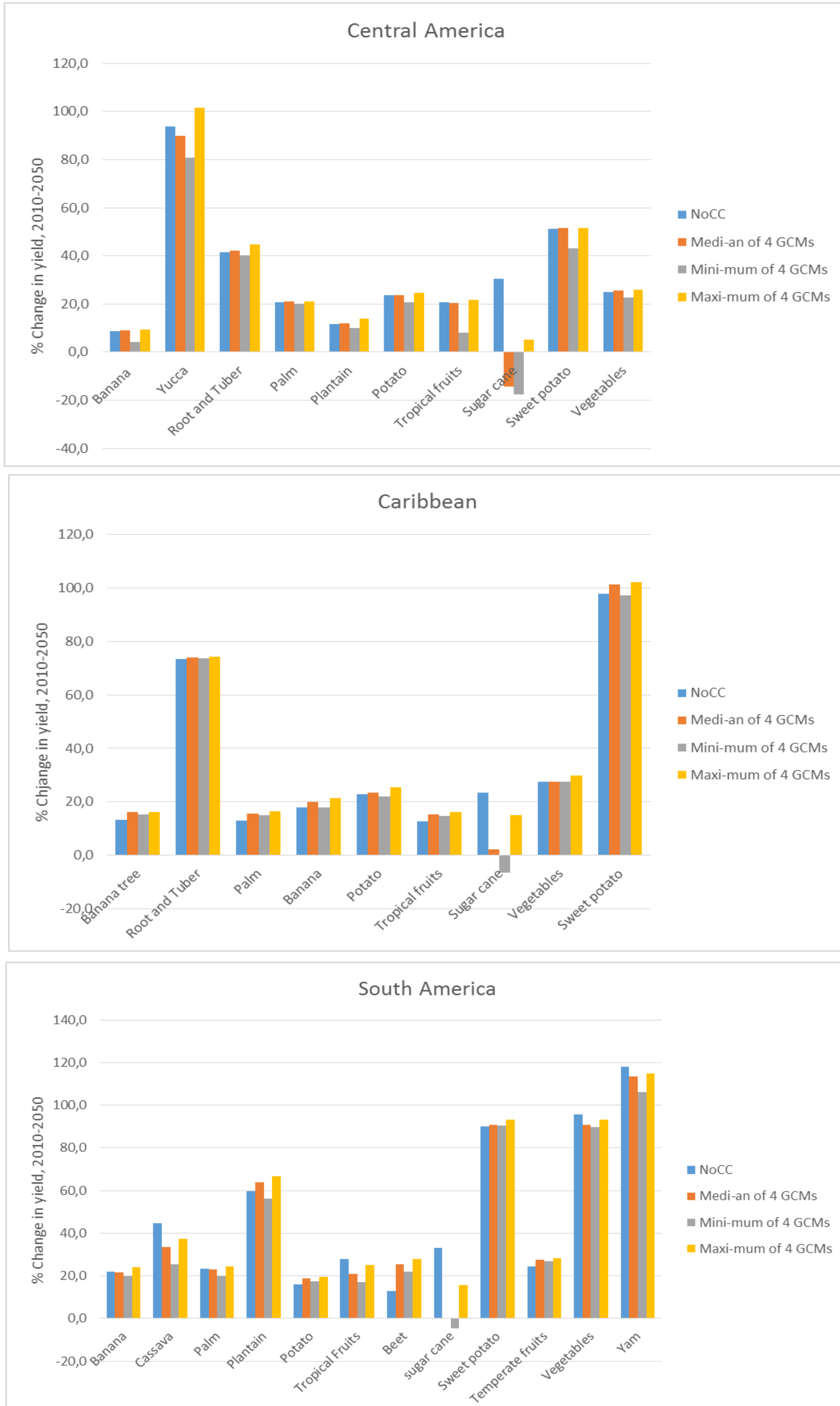

Figure 4. Percentage of Change in Performance between 2010 and 2050 under scenario of climate change for crops in Latin America and the Caribbean. Results of the IMPACT model.

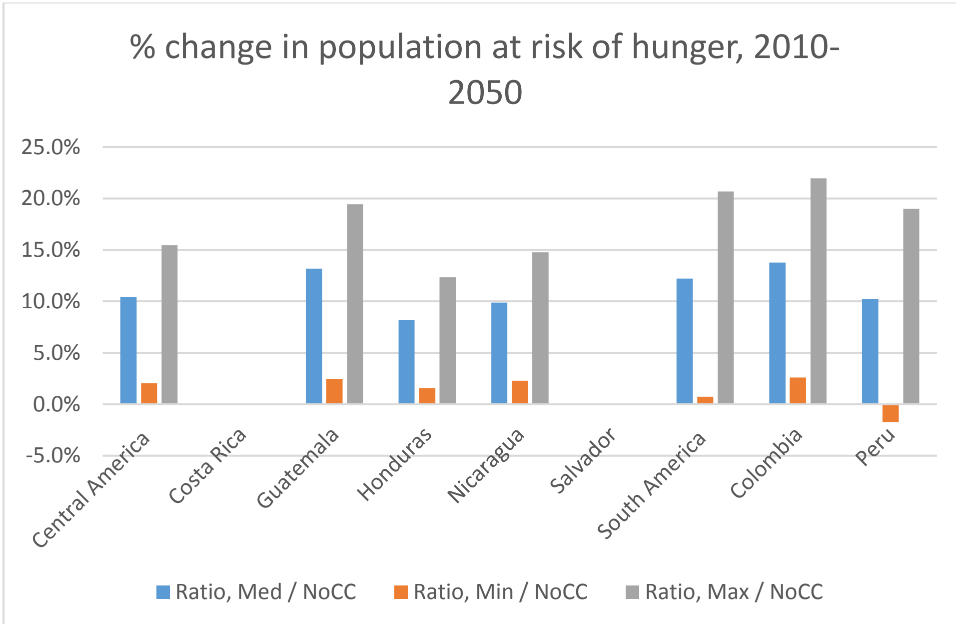

Figure 5. Rate of change of population at risk of hunger under climate change scenarios (2010-2050). IMPACT model results

3. Implementation cases

Because the IMPACT model has a modular structure that allows the integration of different physical, biophysical and socio-economic analyses, it has become a flexible tool for policy analysis and decision-making. This model has been used in the analysis of the links between agricultural production and food security at both regional and national levels. It has also been used for crop analysis and for interdisciplinary projects based on scenarios.

Food security analysis at national level

Among the applications of the IMPACT model in the food security analysis at the national level are three studies developed in Africa. The first of these presents a robust analysis of the threats facing food security in eleven countries[1] in West Africa and the implications of climate change on it. In this study, simulations of both economic and biophysical processes that influence food security were carried out, using the IMPACT model, the hydrological modeling component of IMPACT and the software DSSAT (crop model). As a result, it was identified that climate change will modify rainfall patterns, reducing their intensity in most countries and in turn a temperature increase (2°C) will occur. High temperatures will affect the physiology of plants, including staple crops in the region. This situation could be aggravated by the genetic inability of plants to survive extreme conditions. This will have far-reaching consequences for poor and marginalized populations, who depend on agriculture for their livelihoods and in turn have less adaptive capacity. In addition, these populations are more vulnerable because their economy depends on rainfed agriculture. According to projected climate change, the productivity of staple foods is

[1] West African countries included in the study: Benin, Burkina Faso, Ivory Coast, Ghana, Guinea, Liberia, Niger, Nigeria, Senegal, Sierra Leone and Togo.

expected to be negatively affected, mainly in crops such as sorghum, cassava, and peanuts. A major challenge is to increase agricultural production among resource-poor farmers without exacerbating environmental problems and at the same time adapting to climate change (Jalloh et al., 2013).

The second study at country level conducted in Africa corresponds to the analysis of climate change threats to food security in eight countries[2] in Southern Africa. Like the previous study, the same models were used to perform the analyses. The results of the IMPACT model indicate that maize production will increase by 2050, however in some countries production will not meet demand, increasing net imports of this crop and generating an increase in price above $ 200/t. This will make it difficult for people below the poverty line to access this food. In the case of crops such as sorghum and millet, an increase in production is expected by 2050. In general terms, small farmers contribute the highest proportion of agricultural production in the countries analyzed, which is why the agricultural sector is considered very vulnerable to the impacts of climate change (coupled with low agricultural yield). In addition, the population analyzed has high rates of population growth and higher rates of evapotranspiration, so that greater pressure on water resources and immigration from the countryside to the city can be expected (Hachigonta et al., 2013).

Finally, the third country-level study in Africa is the analysis of the threats to food security faced by ten countries in East[3] Africa. Like the two studies mentioned above, in this study the same models were used to perform the analyses. The climate models indicate that for the countries of East Africa an increase in the minimum temperatures is expected, along with more erratic and strong rainfall, as well as a reduction of the production of crops (especially rainfed crops) and coffee. The results of the IMPACT model indicate that the production of some crops will increase because of the expansion of cultivated area and others due to technological progress. Likewise, disease increases are expected in crops such as coffee, cassava and plantain. Given the above, it is necessary to formulate policies and investments focused on the growth of agriculture and productivity of small farmers to address climate change (Waithaka et al., 2013).

Other cases of application of the IMPACT model at the country level can be found in Ye et al. 2014 (analysis for China) and Takle et al. 2013 (analysis for the United States).

Food security analysis at the regional level

At the regional level, the IMPACT model has been used in the Arab Region to identify changes in food security and agricultural production by 2050 for the formulation of policies aimed at protecting food security in the region. The model was developed based on the comparison of a base scenario and two scenarios considering investment strategies and policies for the agricultural

[2] Countries in southern Africa that are part of the study: Botswana, Lesotho, Malawi, Mozambique, South Africa, Swaziland, Zambia and Zimbabwe.
[3] East African countries analyzed in the study: Burundi, Democratic Republic of the Congo, Eritrea, Kenya, Madagascar, Rwanda, Sudan, Tanzania and Uganda.

sector. These scenarios included projections of climate change. The results of the IMPACT model indicated the importance of agricultural research to guarantee food security in the region, as well as investment in irrigation systems, market improvement and better management of natural resources (Sulser et al., 2011).

Analysis of agricultural products

The study by Scott et al. (2000) presents the use of the IMPACT model to analyze agricultural products. This study aimed to identify the production, use, trade and economically important projections of crops such as roots and tubers for contributing to the food, nutrition, and income of the world's poorest farmers. In this case, the analysis incorporated a baseline scenario and an alternative scenario of high demand and tuber and root production in 2020. The results of the baseline scenario indicate that the relative economic importance will decrease in relation to the rest of the major food commodities in the next three decades, despite the decrease of other crops of nutritional importance. On the other hand, the alternative scenario of high demand and production indicates that the economic importance of crops such as roots and tubers compared to commodities will increase slightly. In this sense, the authors suggest that a better understanding of the production, utilization, trade, and future estimates of the economic importance of these crops has potentially far-reaching implications for investments in agriculture.

Interdisciplinary projects based on scenarios

One of the interdisciplinary projects that have used the IMPACT model for their analysis is the "World Water and Food to 2025: Dealing with Scarcity", which mentions that food security in the 21st century is likely to be closely linked to water security. In this sense, the IMPACT model analyzes various policies and investment scenarios associated with food security and water resources. The analysis shows the way in which policies are formulated and water resource management is actually impacting the state of food security. In this sense, by improving water resource management, policies and increased investment, it has a positive effect on farmers and other water users (Rosegrant et al., 2002).

Methodology 3: Gender toolbox

1. *Description of the Methodology*

1.1. Literature review of the methodology

Gender refers both to the visible and invisible social and cultural roles that men and women engage in and the power relations between them, which often determine access to and control of resources and decision-making (Momsen, 2004). These socially constructed differences have a profound effect on how men and women, the old and the young, manage their agricultural practices and natural resources, and respond to the changing climate. The social constructions carry specific roles, status and expectations that manifest at different levels, from the smallest unit of a household, to community and national levels. Since they are social constructs, they vary from one culture to another and change over space and time.

Gender inequality arises when men and women experience different opportunities and capabilities in terms of access to and control over resources, decision making opportunities and activities undertaken. In terms of impact of climate change, gender dimensions of vulnerability exist because of the differential access that men and women have to the social and environmental resources that are required for adaptation. These can include education, health, finance and credit, knowledge and the ability to make decisions to adapt. The relatively higher vulnerability of women and girls to weather-related disasters such as severe storms, floods and droughts, is well documented.

One of the reasons for their higher vulnerability is socially and culturally determined gender roles. For example, a) during drought men and young men are permitted to migrate to other areas while women and girls stay behind to tend to the homes, increasing their labour burden and potentially making them more vulnerable to shocks such as floods, b) men can access credit since they have resources to use as collateral, and c) boys attend school for more years than girls and thus access better opportunities, such as non-agrarian livelihood strategies. Recognition of these realities is an important prerequisite to ensuring that adaptation and mitigation strategies are gender responsive. It is critical to point out that adaptation and mitigation programs and projects that are gender blind will most likely run the risk of reinforcing the existing gendered nature of vulnerability.

The Gender and Inclusion Toolbox: Participatory Research in Climate Change and Agriculture (Jost et al., 2014) is a tool to document the differential vulnerability of men and women to climate change and to identify gender-responsive interventions. It is designed to assess gender differences, establish a baseline analysis (what is known) and define ways in which gender is integrated right from project design, through implementation, monitoring and finally evaluation. Essentially, the toolbox can be used to:

- Undertake analysis of gender differences in vulnerability as well as adaptation and mitigation strategies.
- Document sex-disaggregated data on access to productive resources, labor and time use, resource endowments (wealth), and membership in farmer and social organizations.
- Analyze adequacy of existing institutions and policies to address the impacts of climate change on gender.
- Use all of the above gender disparity information to inform gender responsive climate agricultural interventions.

It is important to point out that the Toolbox also increases the knowledge and strengthens the participatory skills of researchers/project implementers. The participatory exercises included in the toolbox also prepare the mindset of the researcher/project implementers, including how to understand and discover the difference between sex and gender and how to build trust and confidence with community members.

1.2 Description of the methodology proposed

The Gender and Inclusion Toolbox is a resource and toolbox for NGO practitioners and programme designers to develop gender sensitive and socially inclusive climate change programmes in rural development. It is primarily a qualitative research methodology that provides participatory tools and methods for situational analysis of knowledge, climate smart agriculture, climate information services and mitigation at the community and household levels. The toolbox can be used to gather data on gendered differences in farming practices, resource availability, access to climate information, institutions and women's empowerment. It does not provide an opportunity to analyze components of food systems that can be affected by climate change such as tradeoffs in land use (intensification vs extensification), risk assessment and management, food loss and waste (pricing, transport and storage), nutrition and health, among others.

Specifically, the Toolbox provides definitions of basic concepts (that are sometimes confusing) such as gender and social analysis, climate change, participation, and qualitative research. It offers an opportunity for reflective research that supports communities and researchers to continually learn various components of their farming systems in a changing climate. The toolbox allows for an exploration of the relationship of gender to other factors such as labour, resources, wealth, empowerment, climate information, knowledge of environment, time management and changing farming practices. The manual for the implementation of the gender toolbox can be consulted at the following link: http://hdl.handle.net/10568/45955

Some of the broad questions that can be answered by the toolbox are:

- How is the climate changing within the community and how have men, women and the youth adapted to the changing climate?
- What adaptation and mitigation strategies are appropriate for men and women given their seasonal and daily calendars, and access and control of resources, and mobility opportunities?
- What institutions and policies can support a gender responsive adaptation to climate change?

The toolbox supports the development of limited quantitative data. This should not be considered a drawback because we can draw tools and methods from other gender frameworks to generate quantitative data. For example, the FAO Agri-Gender Statistics Toolkit[4] is an excellent tool for collecting gender statistics, and/or sex- disaggregated data on agriculture, fisheries, livestock production, fisheries and forestry. The Agri-gender statistics toolkit provides eight questionnaires for assessment of gender related agricultural production including agricultural population and households, access to productive resources, production and productivity, destination of agricultural produce, labour and time-use, income and expenditures, membership of agricultural/farmer organizations, food security and poverty levels.

The GACSA Practice Brief "*A Gender-responsive Approach to Climate-Smart Agriculture: Evidence and guidance for practitioners*" provides a set of guidelines for understanding and evaluating a gender-sensitive approach to CSA. It begins with an overview of how the particular

[4] Agri-Gener: http://www.fao.org/gender/agrigender/agri-gender-toolkit/en/

needs, priorities, and realities of men and women can be recognized and adequately addressed in the design and application of CSA to ensure that women and men benefit equally (Nelson and Huyer, 2016).

It discusses the implications of gender equality for each of the three “pillars” of CSA: 1) sustainably increase agricultural productivity and incomes; 2) adapt to and build resilience to climate change; and 3) reduce and/or remove greenhouse gas emissions, where possible. It then outlines the challenges to successful gender-responsive CSA approaches, as well as the differing capabilities, vulnerabilities and situations of women and men. For example, lack of political will or commitment to gender equality of leadership at different levels or cultural barriers limiting women’s participation and leadership in activities and organizations can pose barriers to gender-responsive approaches. Men and women within the same agricultural household will often pursue separate but interrelated livelihoods, and incorporate different technology and production management options as a result. It is therefore important to look at how these differences may affect men’s and women’s participation in more sustainable agricultural practices and the consequent benefits (Nelson and Huyer, 2016).

Five criteria are identified to determine the gender-responsiveness of CSA (Nelson and Huyer, 2016):

1. The development and application of the practice have been informed by gender analysis
2. All work related to the practice has involved the participation and engagement of men and women, in particular those who implement the practice
3. Efforts are made to reduce the constraints to uptake of the practice
4. The CSA practice results in immediate benefits for men and women
5. The practice translates into long-term benefits for both men and women

The brief concludes with suggested gender-sensitive indicators to measure changes in increased control of productive assets, participation in decision-making, knowledge, changes in behavior and attitude, awareness, empowerment, improved economic status, food security and nutrition of women and men, among others.

2. Results/Outputs

The gender toolbox facilitates the development of gender-sensitive and socially more inclusive research relevant to both men and women, identifying gender roles and relationships at the interpersonal, family, and community level in the agricultural sector. This approach allows for analyses based on the knowledge of the community (bottom up) and not based on the knowledge of experts, thereby allowing the participation of men and women in the debate on climate change. As a result of this tool, data analysis is obtained, which explain how women and men adapt to climate change and strengthen their food security (Jost et al., 2014).

Gender roles and responsibilities assigned by society and culture determine how each group experiences the effects of climate change differently. Understanding the different options that men and women adopt to reduce their vulnerability to climate change, which is very important to develop strategies and policies. Given the above, the gender toolbox provides gender-sensitive information for the development of policy planning around climate change (Jost et al., 2014).

With regard to the issue of public policy, there are two key elements needed improve gender integration in CSA. The first is the insufficient attention paid to gender (and its inequities) in agricultural systems in general and, crucially, in agricultural policy in particular. Second, most governments generally fail to address the different resources, adaptive capacity, needs, etc. that women, men and youth have with respect to dealing with the impacts of climate change. There have been several commitments to tackling gender inequality in government policy. These commitments call for countries to take appropriate measures, including legislation and the allocation of resources to ensure women's development and advancement especially in developing countries.

To achieve gender equality for each of the three pillars of CSA mentioned above, appropriate gender transformative legislation at national level is therefore needed. This national legislation must be informed by scientific evidence of sex-disaggregated data. The three resources mentioned in this methodology, that is, a) Gender toolbox, b) FAO Agri-Gender Statistics Toolkit and c) GACSA Practice Brief can be used to highlight gender inequalities by identifying key differences between women, men and the youth in relation to CSA and the socio-cultural determinants of agricultural practices in order to support policy change. Once gender (and/or sex) -disaggregated data has been collected, quantitative trends and qualitative observations can be constructed that help make the case for gender-transformative CSA planning, gender responsive budgeting, monitoring and evaluation, right from local level to national levels. A few key points that policy makers need to keep in mind in order to develop and implement gender responsive CSA/agricultural policy include:

- Use of scientifically sound data collection tools for high-quality gender (and/or sex)-disaggregated data that generate different formats (quantitative and qualitative) and at the appropriate level – from village to national level. These data will raise awareness and the data will be the basis for the formulation, implementation and evaluation of gender transformative public policies, plans and programmes.
- Political commitment to invest in the use of gender toolboxes for data collection and ownership of the data collected.
- Involvement of key stakeholders especially women and youth farmers at all levels.
- Political commitment of financial resources and regularly trained human resources.
- Regular monitoring and evaluation (including external review) of the policies on how they are reducing or increasing gender inequalities.

3. Implementation cases

The Gender and Inclusion Toolbox has been used in Ghana, Uganda and Bangladesh by CCAFS in partnership with ILRI, IWWI, CARE International and FAO (Jost et al., 2016). In Ghana, it was tested in the Upper West Region to explore resources that men, women and youth have access to as they deal with a highly variable climate, how they access climate information, trends in adoption of CSA practices, and the institutional arrangements that enable or hinder uptake of CSA. For example, results from this study demonstrate that gender responsive CSA practices are essential because men, women and the youth have different sources of seasonal and daily weather and belong to different organizations. Additionally, men are more mobile than women and travel longer distances away from the community. They use bicycles and lorries while women travel on foot (Naab and Koranteng, 2012).

Research in Bangladesh found that men and women engage at different stages of the value chain. For example, in crop production, men are responsible for primary production and marketing while women come on board during post-harvest management. The reverse is true for livestock production where women provide the labor for managing cattle while men market milk and other livestock products. The same trends of gender disparity in responsibilities in crop and livestock management are observed in Uganda.

In addition, in the last two years, the use of this tool has been promoted in Central American countries through participatory workshops. Recently, the Specialized Center for the Care of Women (CEAMUJER, for its acronym in Spanish) has used this methodology to carry out a participatory diagnosis in the framework of the project on integrated water resources management in the rural community of Valle de Casa. This tool has allowed for the participants to identify changes in climate, vegetation, livelihoods and community water resources.

Methodology 4: Surveys and databases as tools to know and monitoring the state of the agricultural sector

To know the state of the agricultural sector at the farm level, household surveys are an important tool for data collection and subsequent analysis, providing real and useful information to understand agricultural dynamics and planning for the future, including food security and nutrition. Likewise, the collection of agricultural data through easy access platforms is a way to improve the analyses of the sector to make contextualized decisions. Within the household surveys is the Rural Household Multiple Indicator Survey (RHoMIS), which quickly characterizes a set of standardized indicators encompassing the entire food system (productivity, food security, nutrition, trade, etc.). On the other hand, the Integrated Modelling Platform for Mixed Animal Crop systems (IMPACTlite), allows the capture of information on different agricultural activities and characterizes the main systems of agricultural production. These tools are described below.

RHoMIS, Rural Household Multiple Indicator Survey

1. Description of the methodology

1.1. Literature review of the methodology

Achieving climate smart agriculture depends on understanding the links between farming and livelihood practices, other possible adaptation options, and their collective effects on farm performance. Reliable indicators of farm performance are needed in order to model these links, and to subsequently design interventions that meet the differing needs of specific user groups. However, the lack of standardisation of performance indicators has led to a wide array of tools and ad-hoc indicators that are shaped by farm management and the wider social-environmental context.

This limits our ability to compare across studies and to draw general conclusions on relationships and trade-offs between farm characteristics and management on one side, and nutrition, food security and poverty on the other. RHoMIS (Rural Household Multiple Indicator Survey) is a household survey tool designed to rapidly characterise a series of standardised indicators across the spectrum of agricultural production and market integration, nutrition, food security, poverty and GHG emissions. The survey tool takes 40-60 minutes to administer per household using a digital implementation platform and a mobile phone or tablet.

The survey tool was designed according to the following five principles:

1. The survey has to be rapid enough to avoid participant fatigue or annoyance, and to keep costs low to allow for larger sample sizes on a limited budget.
2. The survey has to be utilitarian, in that all questions asked in the survey are being used in pre-defined analyses in order to minimize superfluous data collection.
3. The survey has to be user-friendly, so that all participants in the process of collecting and analyzing data can perform the tasks with minimum hassle, thereby increasing speed and improving data quality.
4. The survey has to be flexible, so that it can be modified easily to suit the local context of the farming systems and farm households where it is deployed.
5. The data gathered has to be reliable, in that questions should be easy for respondents to understand and the answers should be based on observable criteria or respondents' direct experience rather than abstract concepts.

A detailed description of the background to the survey approach can be found in Hammond et al. (2016).

1.2. Description of the methodology proposed

As previously mentioned, the RHoMIS tool is an agricultural household survey that can be performed using smartphones or tablets. The information provided in the survey is directly uploaded to a platform, where the indicators are calculated through specific programs, such as the software R. The tool has the option to include additional modules in the survey, allowing the incorporation of indicators and information adjusted according to the local needs of the study that is being developed. (Hammond et al., 2016).

The indicators captured by the RHoMIS tool are chosen to represent important factors across agricultural production, gender equity, nutrition and poverty relationships, while also capturing key indicators of interest related to climate smart agriculture (i.e. greenhouse gas emissions). In total the survey tool now quantifies 17 different indicators and is constructed in a modular way, with each module collecting the information needed for calculating the performance indicator of interest. New indicators of interest to the user can therefore be added easily. Among the indicators of the tool are food availability, diet diversity, household food insecurity access scale[5] (HFIAS), poverty progress index, gender equity, estimation of greenhouse gasses (GHG) at the level of farms, productivity, value of production, farm income and intensity of GHG emissions.

Collected data are uploaded to a server, and the data labels in the database are linked to a set of automated analysis procedures that enable immediate cross-site bench-marking and intra-site characterization. The survey quantifies the source of the different food items consumed during the good and bad periods in the year: are they purchased or are they based on on-farm production? This allows researchers to analyze outcomes through different food system impact pathways, either through stimulating the availability of different food items in the market, or through stimulating the diversity of the food system via on-farm production.

2. Results/Outputs

The tool has been applied in a wide range of systems across different regions such as Central America, sub-Saharan Africa and South East Asia, and the tool has generated key quantitative information on the current farming strategies that farmers use, and how these together with the productive resources the farmers have combine to generate their food security and nutritional status. The tool has also been applied in East Africa to assess changes in smallholder farming systems over time, and to assess how smallholder farmers try to cope with climate variability (Fraval et al., 2016).

The indicators in current applications of the RHoMIS tool give an adequate snapshot of the sites, and enable appraisals of the 'CSA-ness' of farm strategies. Results can be used in a post-hoc project evaluation of specific CSA interventions. The applications are not limited to CSA, however, as the RHoMIS tool is intended to be a generic indicator framework. Context-specific adaptions could

[5] Household Food Insecurity Access Scale (HFIAS): this indicator estimates the prevalence of food insecurity and is based on the idea that the experience of food insecurity (access to food) causes predictable reactions, whose responses can be captured and quantified through a survey and represented on a scale. There are nine questions that serve to identify the general increase in food insecurity severity (called occurrence questions), and nine questions that are used as a follow-up to each occurrence question to determine the frequency of the condition occurring. Respondents are asked about food insecurity during the worst month ('bad season') of the previous year, and the frequency options can be daily, weekly, monthly or never / less than a month. The indicator is rated on a scale of 0 to 27, where a higher number means that a household experiences greater food insecurity.

expand analysis to include integrated natural resource management, integrated nutrient management, conservation agriculture, organic agriculture, integrated pest management, agroforestry, integrated soil fertility management and many others. It can also be used to construct farm types to aid intervention targeting across farming systems or generate the needed inputs for modelling exercises for ex-ante impact assessments. Indicator standardization provides multiple benefits, but it is an area of research that has been largely ignored in the current literature.

3. Implementation Cases

The RHoMIS tool has now been applied in a series of development oriented projects (funded by amongst others USAID, BMZ, NORAD, DFID and IFAD), with datasets collected in sites in Guatemala, Honduras, El Salvador, Nicaragua, Mali, Burkina Faso, Kenya, Tanzania, Malawi, Vietnam, Laos and Cambodia, resulting in a database with quantitative information on ~5000 farm households, and with many more applications in the pipeline later in 2016 and early 2017. At the moment, a webportal is being set up through which the data will be freely distributed along with available data collection tools, analysis tools and visualization tools. The first datasets will be distributed through this webportal by the end of 2016 and early 2017. The first data that will be put online will be data collected on 800 farm households in five sites throughout Nicaragua, El Salvador and Guatemala.

The study carried out by Hammond et al. (2016) presents the applications of RHoMIS, in which the tool was used to collect information at the household level in two contrasting sites vulnerable to climate change. The first site is Trifinio (the border area between El Salvador, Guatemala and Honduras) in Central America; and the second was the Lushoto district in Tanzania (a biodiversity hotspot). Households for the application of the survey were selected by the cooperating organizations, considering some households candidates from an experiment to introduce a variety of beans; the remaining percentage of the population was selected at random. The results of the study show that in both regions the indicators of food security and dietary diversity in the household are low, indicating poor nutrition and food insecurity. However, in the case of Trifinio, the values in the indicators of productivity and availability of food are high, while the indicators of crop diversity are low; the latter is related to the low diversity of the diet in the household. For example, in Guatemala the phenomenon of hidden hunger is presented. Thus, the households surveyed have a sufficient intake of calories, but not enough total intake of nutrients or micronutrients, related to the low diversity of crops, mainly because their production is oriented to the cultivation of corn and beans. In contrast, in the case of Lushoto, farms have more crop diversity and more livestock, which generates higher scores in dietary diversity, although the total available energy is lower than in Guatemala.

With regard to CSA interventions, the study made comparisons between practices aimed at intensifying production systems[6] and practices aimed at improving the efficiency of production systems such as efficient management of nitrogen fertilizers, the increase of livestock weight and

[6] In some cases, it has been identified that agricultural intensification can reduce the intensity of greenhouse gases in large farms (Hammond et al., 2016).

use of better quality food for livestock with the aim of reducing emissions. The study found that practices aimed at improving the efficiency of production systems contribute to reducing emissions and improving food security, due to the fact that the productive systems present in the study areas are small-scale, particularly in Trifinio. In addition, the application of the RHoMIS tool identified that the effectiveness of CSA interventions not only depends on the strategy or the intervention itself, but is also determined by an interaction between the characteristics of the agricultural household and the management of the farm. This is one of the most important uses of the RHoMIS tool (Hammond et al., 2016).

IMPACTLite, Integrated Modelling Platform for Mixed Animal Crop systems

1. Description of the methodology

1.1. Literature review of the methodology

Several studies have tried to understand how farmers' decisions are influenced by the socioeconomic, environmental and sociopolitical characteristics of their region. Although standard databases for data capture have been established taking into account the components of the systems (crops, livestock, soil), few have been developed for data capture at the system level (Herrero et al, 2005). Based on this, the Integrated Modeling Platform for Mixed Animal Crop system (IMPACT), developed by the International Livestock Research Institute (ILRI) was created to encourage the exchange of data through the use of standard protocols, allowing the use of tools to facilitate the analysis of various production systems. Since its inception, the tool has had improvements, the most recent of which has been called IMPACTlite, which has been developed in conjunction with CCAFS. This improved version has a friendlier interface, being easier and more efficient to use.

IMPACTlite provides a unified framework for collecting detailed information on agricultural resources, agricultural management strategies, agricultural productivity and domestic economy in households (Yasub, 2013). Gender-sensitive information on resource control, land ownership and the allocation of activities is included in the data set that the platform compiles (Odongo, 2014).

1.2. Description of the methodology proposed

The IMPACTlite platform is made up of 17 modules for the collection of agricultural information. The first module corresponds to information related to household members, including information ranging from issues related to family structure to issues of education. With regard to the second module, it corresponds to information on the distribution of plots, requirements and production, types of irrigation systems, among others. The third module of the survey refers to the classification of agricultural activities within the farms (Silvestri et al., 2014).

The data collection modules can be modified, which means it is possible to introduce new questions or eliminate others, according to the context of the region. The user manual for the implementation of this methodology can be found in the IMPACTlite[7] database.

2. Results/Outputs

IMPACTlite collects characteristic data that can generate typologies of agricultural households, provide data for simulation models and generate information as a basis for impact assessments, with special attention in the tropics (ILRI, n.d.).

Another type of information that is collected by the survey modules is related to the amount of land, land ownership, labor, types of agricultural activities and inputs used, amount of production, main crops produced, types and use of crop residues, livestock inventory, livestock activities and inputs, type and amount of feed for livestock, and types of livestock products. It also investigates the household composition, household income and expenditure, including a gender approach, and collects information on the consumption of both farm and non-farm products and property ownership (Silvestri et al., 2014).

The IMPACTlite platform can easily download the data and figures that have been generated. It is also possible to replicate the survey at other sites and even to make comparisons with existing data. In addition, users of this platform can modify and generate other surveys with existing tools.

One of the uses of the data generated by IMPACTlite is the development of models to carry out impact assessments of alternative crop management or a new policy intervention. Additionally, it allows the characterization of the crops, generating a better knowledge of the system's performance, to evaluate different management scenarios (Herrero et al., 2005). In addition, IMPACTlite data allow for an ex-ante assessment of the impacts of climate change on food production and consumption, identification of adaptation and mitigation measures, as well as indicators of livelihoods and emissions to estimate the impact of agriculture on the environment (Rufino et al., 2012).

Currently, IMPACTlite has a database with information collected from 15 sampling sites in the countries of East Africa, West Africa and South Asia, which can be consulted at the following link *http://data.ilri.org/portal/dataset?q=impactlite.*

3. Implementation cases

One example of the application of IMPACT Lite is Douxchamps et al. (2015), who used the tool to collect data to explore the linkages between selected agricultural adaptation strategies (crop diversity, soil and water conservation, trees on farm, small ruminants, improved crop varieties, fertilizers), food security, farm household characteristics and farm productivity in three contrasting agro-ecological sites in West Africa (Burkina Faso, Ghana and Senegal). The data collection

[7] The user manual can be found at the following link: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/24751&studyListingIndex=0_d1e3eb1ade9384807a3162ac334f

protocol is described in detail in Rufino et al. (2012). For the three study sites, data from 600 households were collected using a stratified sampling strategy. The data are available online at https://thedata.harvard.edu/dvn/dv/CCAFSbaseline/ (Silvestri et al. 2014).

In this example, the focus was on one of the key pillars of food security, i.e. food availability, where the goal is to obtain sufficient quantities of food of appropriate quality available at the household level throughout the year. Food security and food self-sufficiency ratios were calculated. The food security ratio is the ratio of the energy consumed by a household, from on-farm as well as purchased products, divided by the energy requirements of the household. Food self-sufficiency ratio is the ratio of the energy consumed by a household from on-farm products, divided by the energy requirements. Households were considered food secure if the ratio is larger than one.

Results from the work demonstrated that differences in land area per capita and land productivity largely explained the variation in food security across sites. Income increased steadily with land size, and both income and land productivity increased with degree of market orientation. The adoption of agricultural adaptation strategies was widespread, although the intensity of practice varied across household types. Adaptation strategies improve the food security status of some households, but not all. Some strategies had a significant positive impact on land productivity, while others reduced vulnerability resulting in a more stable cash flow throughout the year. The data set is forming one part of a baseline study for these three sites, and the surveys will be repeated in the future (using the same survey instruments) to monitor progress in key indicators such as household income and the food security indicators described above.

Finally, within this type of tool, it is important to mention the baseline studies implemented by CCAFS, which constitute a key component of CCAFS monitoring, learning and evaluation. Baseline data are collected at the beginning of the establishment of the Climate-Smart Villages. The purpose is to monitor key changes in behavior and practices over time, seeking not to attribute the changes to a specific intervention, but to observe the changes and infer whether or not farmers' resilience is increasing.

These studies contribute to prioritizing future research and supporting the relationship with strategic partners as part of research for development. CCAFS baseline studies are conducted at the household, community, and organizational level. The first dimension is where the aspects related to food and nutrition security are assessed. The number of foods consumed per household that come from the farm is one of the indicators of the study, as well as the number of foods the household has to buy off-farm. The methodology suggests a food security index based on the number of months the family does not have enough food to supply their minimum food. Similarly, indicators are established to determine how many major crops are associated with food security and food sources outside the home. Analyses of the baseline studies provide information to prioritize the options for Climate Smart Agriculture that should be promoted and implemented to reduce the negative impacts on food security in a changing climate context.

Methodology 5: Climate-Smart Villages

1. ***Description of the methodology***

1.1. Literature review of the methodology

The challenges that farmers face today regarding climate are becoming an increasingly important barrier to maintaining the productivity of agricultural activities. Today, about 32-39% of global agricultural output is explained by the climate, which translates into annual production fluctuations of approximately 2 to 22 million tons of crops such as maize, rice, wheat and soybeans (Ray et al., 2013). In addition, FAO's food production analysis based on population growth projections for 2050 foresees the need to increase world production by at least 60% to meet food demand, and at the same time the IPCC estimates that global food prudction will be reduced by at least 5% for every 1°C increase in temperature.

In this sense, to maintain the growth of agricultural production while minimizing the impact on the environment, it is crucial to have sustainable food production and achieve sustainable development goals. Climate Smart Agriculture (CSA) seeks to contribute in this way through three pillars: i) to increase agricultural productivity sustainably, to support equitable increases in agricultural incomes, food security and development; (ii) adapting and strengthening the resilience of food security systems to climate change at multiple levels; and (iii) reduce greenhouse gas (GHG) emissions from agriculture (including crops, livestock and fisheries).

While there are efforts to promote CSA at the global level, the generation of evidence on how much the different practices, technologies, services, processes and institutional arrangements contribute to its pillars is critical. This evidence will be useful to identify the different synergies and tradeoffs between the pillars in the various agroecological and socioeconomic contexts of rural populations in different countries of the world. Thus, the Climate-Smart Village concept promoted by CCAFS is intended to help close the gaps of evidence through participatory research with multi-stakeholder platforms, with small farmers as their fundamental axis, and their challenges both in terms of the climate-agriculture relationship as those associated with rural development.

Responding to the need for proven and effective CSA options, CCAFS developed the Climate-Smart Villages approach, a scalable approach to improving the resilience of small farmers to a changing climate, and where possible, to reduce GHG emissions. The Climate-Smart Villages bring together relevant knowledge locally and globally, technologies and services of CSA that work in synergy with institutional and policy interventions.

1.2. Description of the methodology proposed

A Climate-Smart Village is a space to generate meaningful and systematic evidence of CSA's efficiency in a real-life setting through the co-development, testing, evaluation and promotion of integrated and innovative CSA options (including technological, social, institutional, financial, value chains and policy) (Figure 6). The Climate-Smart Villages are based on the principles of participatory research under local and context-specific enabling conditions. The approach generates methodological innovations in research for development, through the use of multi-actor collaborative platforms, which facilitate the co-development of scaling-up mechanisms towards landscape, sub-national and national levels. In the establishment of Climate-Smart Villages and the selection of activities to be implemented, the emphasis should always be on scaling, involving partners and processes from the beginning in order to achieve this goal.

In other words, the Climate-Smart Villages are "living laboratories" where communities test, co-develop and adopt integrated CSA portfolios that warrant investment for scaling. The Climate-Smart Villages provide a robust framework for research on enabling environments (specific socioeconomic contexts, financial, institutional and political barriers and incentives) and build the evidence base for a broad CSA scaling up. In addition to being a vehicle for facilitating scaling up, the Climate-Smart Village approach catalyzes the convergence of initiatives and actions across different scales (e.g. national and sub-national adaptation and mitigation programs) to promote sustainable rural development in the context of climate change and variability.

Figure 6. Climate-Smart Villages Components

The Climate-Smart Village approach promotes local and incremental adaptation and the strengthening of local capacities to continue innovation, experimentation and adaptation. The main objective of the approach is to have a positive impact on agriculture dependent communities which includes ensuring the participation of women and marginal communities. As applicable, differentiated gender aspects are evaluated to ensure that the prioritization and development of portfolios of CSA technologies, best practices and services address gender and social inclusion issues.

2. Results/Outputs

The Climate-Smart Villages seek to generate evidence of the effectiveness of CSA technologies, practices and services in conjunction with local communities and stakeholders. This is how these territories serve as a bridge to scale and implement the different options of CSA, which have demonstrated a contribution to food security, adaptation and mitigation to climate change.

Evidence is presented in the Climate-Smart Villages for adaptation options associated with water resources (rainwater harvesting, laser leveling of the soil, micro-irrigation, mulching, change in methods of establishment of the crop); to nutrients (specific site management of nutrients, precision fertilizers, waste management); carbon and energy (agroforestry, solar pumps, conservation tillage, legumes, livestock management); climate management (information and communications technology (ICT) extension services, indexed insurance, stress tolerant varieties); and knowledge (farmer-to-farmer learning, capacity building, community seed banks and cooperatives, crop diversification, crop information and risk management) (Figure 7).

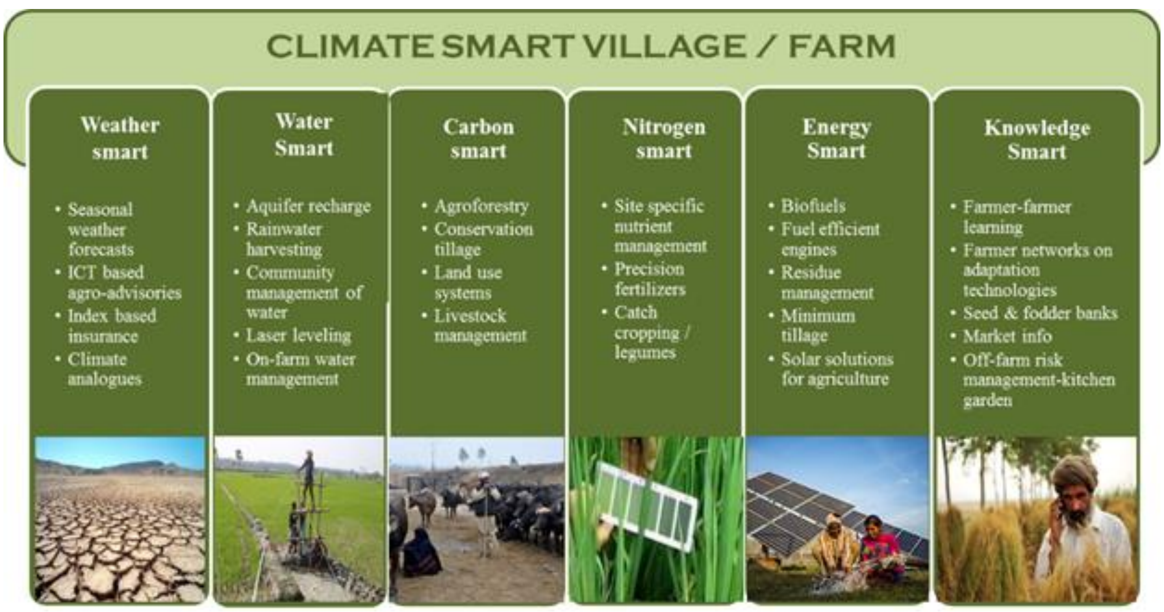

Figure 7. CSA options that can be implemented in Climate-Smart Villages

The expected results are associated with an increase in farmers' production and incomes, as well as income stability at climate risk events and the long-term adaptation to climate change. In the same way, a low-carbon development, the convergence of government programs and the access and generation of climate finance and development. However, there is no fixed package of CSA interventions or an approach that fits all. Interventions differ according to the region, agroecological characteristics, the level of development, and capacity and interest of farmers, actors and local governments.

3. Implementation Cases

Climate-Smart Village in Los Cerrillos (Cauca, Colombia)

The Climate-Smart Village is located in the department of Cauca, Colombia. This area represents one of the regions of the country most affected by the armed conflict. In the context of the next peace agreement, this region is an appropriate laboratory to investigate how an enabling environment could promote rural development based on a territorial approach. This Climate-Smart Village is characterized by significant cultural diversity (indigenous, Afro-descendant), and social and economic problems exacerbated by climate and environmental vulnerability. Despite the various difficulties, the social organization through the Communal Action Boards (JAC, by its acronym in Spanish) has allowed for cohesion among the population that has been strengthened through the land titling process led by the Ministry of Agriculture and Rural Development of Colombia. This environment has facilitated the organic evolution of a stakeholder platform that initially included Ecohabitats Foundation (local strategic partner of CCAFS), the JAC Association that brings together 14 communities and CCAFS. The platform has evolved and now includes other local and regional government institutions, universities, research centers, technical institutions (e.g. SENA - National Institute of Learning Services), among others. This innovative platform supports the co-creation of knowledge through the implementation of CSA practices, technologies and services and the consolidation of a resilient community that takes advantage of changes generated by the climate, but at the same time improves livelihoods and aspires to sustainable agriculture (Figure 8). This is facilitated by taking into account that young people and children play a fundamental role in the implementation of the approach. The young people of the village are co-designing a plausible future for their people and being part of this process, they have been recognized as a fundamental piece of development where they find interesting opportunities to improve the quality of life for them and their parents (CCAFS, 2016).

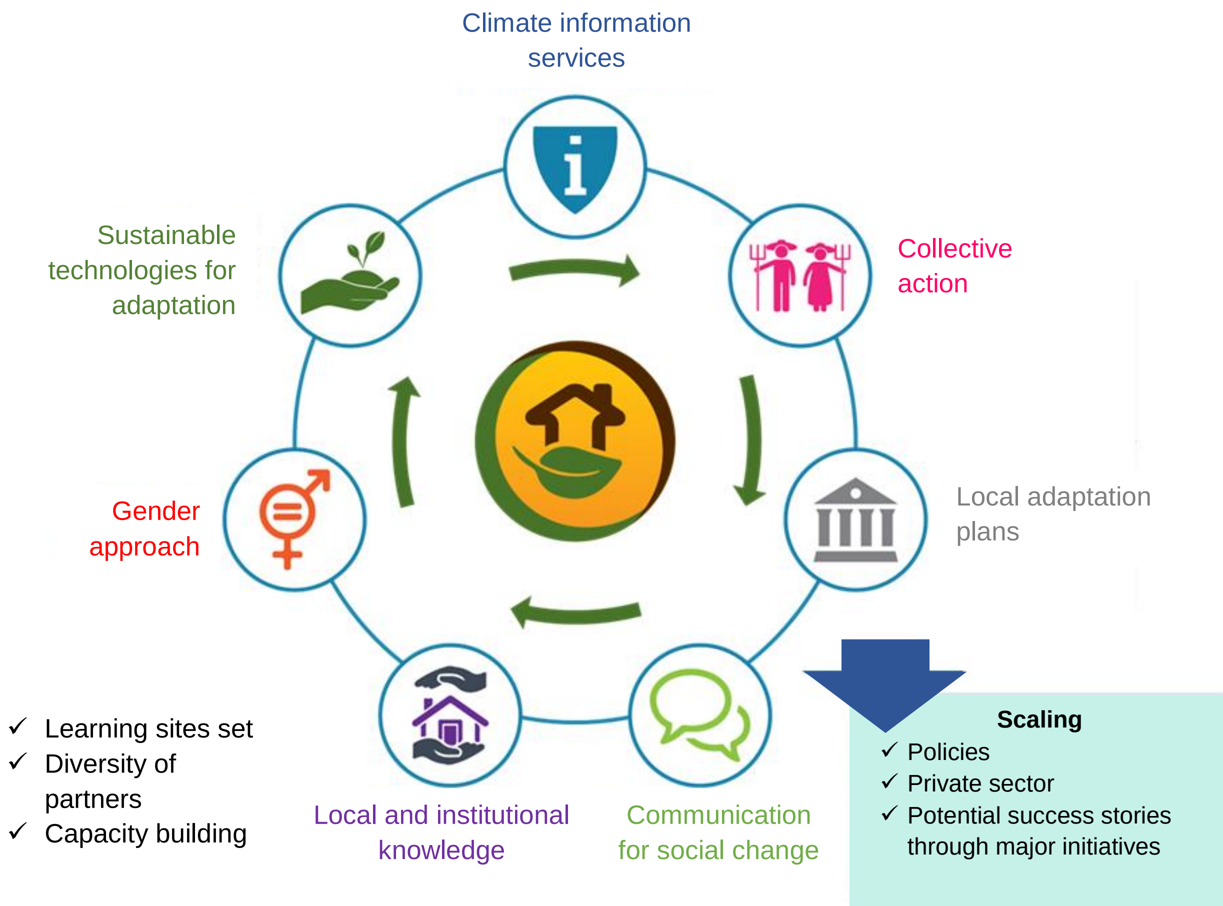

Figure 8. Components considered at the Climate-Smart Villages of Los Cerrillos in Cauca, Colombia

The process began by assimilating and understanding what the climate and its changes mean to the people of the village and their livelihoods. With this information, the community itself developed vulnerability analyses at the farm level to understand threats and identify actions to reduce vulnerability (Figure 9). These actions were prioritized in the local adaptation plans developed by each housheold, taking into account their capacity and risks, including not only their main crops (coffee and sugar cane) but also potential crops that could be included in their agricultural systems (e.g. beans and cassava). These actions are being materialized through the implementation of specific adaptation measures: monitoring of variables at the farm level (precipitation, temperature and humidity) and participation in the Agroclimatic Technical Table of the Cauca Department, rainwater harvesting, vertical orchard construction, circular and traditional biodigesters and evaluation of improved varieties of beans, among others (CCAFS, 2016).

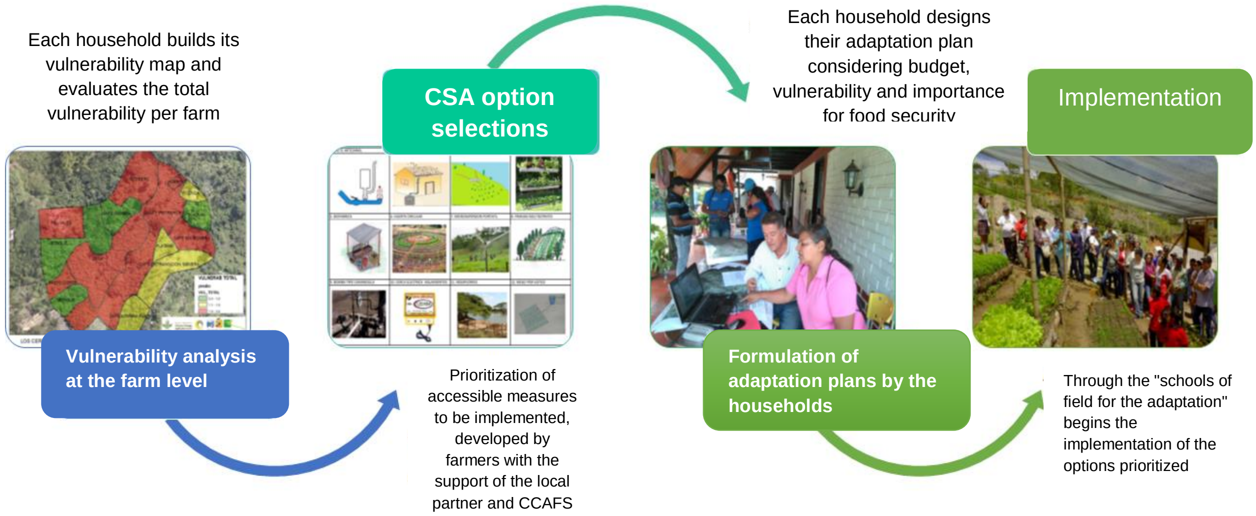

Figure 9. Process of prioritization of CSA options in the Climate-Smart Villages.

As part of the process of implementing local adaptation plans, farmer learning mechanisms and community-based exchanges are being developed in order to share experiences and lessons learned. Similarly, work is being done with young people through training in communication and geographic information systems, and at the same time, the community and academic institutions at the municipal level are serving as a link with national policy. As a result, the Secretary of Agriculture of Popayán, in compliance with the National Education Policy, will include as part of the Municipal Environmental Education process the methodology to formulate local adaptation plans, the Secretary will launch a pilot project in the Climate-Smart Village, and will strengthen the "Young Network for the Environment" at the municipal level (CCAFS, 2016).

The monitoring and evaluation of practices prioritized by the community are being developed within the innovation platform. Indicators of performance improvement, productivity, diversification and others, as well as those related to the evolution and dynamics of the platform itself, are included. Research on GHG emissions in agricultural systems includes modeling GHG flows from different land use options, collecting carbon sink data and potential GHG emissions from selected farms, validation of mechanistic models selected from data from critical areas in terms of GHG emissions, analysis of the impact of climate change mitigation and adaptation strategies taking into account GHG emissions and soil quality (CCAFS, 2016).

Conclusions and Recommendations

Climate change will impact all dimensions of food and nutrition security, from availability, access, use and stability, affecting the entire food system. However, most of the research efforts in the region are focused on the impacts on productivity and agricultural performance. Given the above, it is important to carry out research aimed at understanding the impacts in all dimensions of food and nutrition security, which will allow better long-term planning and continue to meet the region's food security objectives.

Currently there is no comprehensive and accepted analytical framework for understanding the linkages and impacts between climate change and food and nutrition security. This document provides a proposed analysis framework, which includes the interrelationships between the food system and climate change and which highlights the importance of enabling environments. This proposal can serve as a tool for initiating research of this type in the region.

While none of the proposed methodologies offer an integrated assessment or analysis that addresses the interactions between the different components of the food system and the impact of climate change on them, the joint use of several of these methodologies, such as IMPACT and the Gender Toolbox, can contribute to generating a more integrated vision of the interrelationships between climate change and food security. This is supremely useful information for planning and decision-making.

Given the need and importance of knowing the interrelationships between climate change and food and nutrition security in a comprehensive way, and in this way reducing the risks that climate change imposes on the food system, we propose to work on the following four fronts (Campbell et al., 2016): a) changing the research culture to focus on an action-oriented agenda; b) build a portfolio of options for farmers, communities and countries through a participatory process where key actors lead those processes; (c) ensure that the suggested adaptation measures are relevant to those most vulnerable to climate change; and d) promote and generate information on actions combining adaptation and mitigation, while ensuring food security. Following this work agenda will increase the possibility of finding solutions that point to a resilient food system where climate variability is managed satisfactorily in a way that affects as little as possible our most vulnerable populations.

References

Alexandratos, N., Bruinsma, J., 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working paper Rome, FAO.

Cai, W., Borlace, S., Lengaigne, M., van Rensch, P., Collins, M., Vecchi, G., Timmermann, A., Santoso, A., McPhaden, M.J., Wu, L., England, M.H., Wang, G., Guilyardi, E., Jin, F.F. 2014. Increasing frequency of extreme El Niño events due to greenhouse warming. Nature Climate Change 4, 111–116. doi:10.1038/nclimate2100

Campbell, B.M., et al., Reducing risks to food security from climate change. Global Food Security (2016), http: //dx.doi.org/10.1016/j.gfs.2016.06.002i

CCAFS. 2016. The Climate-Smart Village Approach: A novel strategy for scaling up climate-smart agriculture options. To be published. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

CCAFS, 2015. Testing climate and agriculture policy against future scenarios. Available from: https://cgspace.cgiar.org/bitstream/handle/10568/65082/CCAFS%20Future%20Scenarios.pdf

CDKN. 2014. Reporte de evaluación del IPCC ¿Qué implica para Latinoamérica? Climate & Development Knowledge Network (CDKN).

CEPAL, FAO, ALADI. 2016. Seguridad alimentaria, nutrición y erradicación del hambre CELAC 2025: Elementos para el debate y la cooperación regionales. Santiago: Naciones Unidas.

CGIAR. 2015. CGIAR strategy and results framework 2016-2030. Available from: http://www.cgiar.org/our-strategy.

Challinor, A.J., Watson, J., Lobell, D.B., Howden, S.M., Smith, D.R., Chhetri, N. 2014. A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change 4, 287–291. doi:10.1038/nclimate2153

Dijk van, M., Meijerink, G.W., 2014. A review of global food security scenario and assessment studies: Results, gaps and research priorities. Glob. Food Secur., SI: GFS Conference 2013 3, 227–238. doi:10.1016/j.gfs.2014.09.004

Douxchamps S, Van Wijk M, Silvestri S, Moussa A, Quiros C, Ndèye Badiane Y, Buah S, Somé L, Herrero M, Kristjanson P, Ouedraogo M, Thornton P, Van Asten P, Zougmoré R, Rufino M. 2015. Linking agricultural adaptation strategies and food security: evidence from West Africa. Regional Environmental Change, DOI 10.1007/s10113-015-0838-6

Ericksen, P.J., 2007. Conceptualizing food systems for global environmental change research. Global Environmental Change. doi:10.1016/j.gloenvcha.2007.09.002

Ericksen, P.J., Ingram, J.S.I., Liverman, D.M., 2009. Food security and global environmental change: emerging challenges. Environ. Sci. Policy 12, 373–377.

Falconi, C., Torero, M., Maruyama, E., Hernández, M., & Robles, M. 2012. A framework for sustainable food security for Latin America and the Caribbean. Technical Note 441. Inter-American Development Bank.

FAO. 2011. Panorama de la seguridad alimentaria y nutricional en América Latina y el Caribe 2011. Organización de las Naciones Unidas para la Alimentación y la Agricultura.

FAO. 2015. Panorama de la Seguridad Alimentaria en América Latina y el Caribe. La región alcanza las metas internacionales del hambre. Organización de las Naciones Unidas para la Alimentación y la Agricultura.

FAOSTAT. 2016. División de estadística de la FAO. Disponible en: http://faostat3.fao.org/home/E

Fischer, G., M. Shah, and H. Velthuizen. 2002. Climate Change and Agricultural Vulnerability. Vienna: International Institute for Applied Systems Analysis.

Grindle, MS. 2007. Good Enough Governance Revisited. Development Policy Review 25:553-574.

Hachigonta, Sepo, Gerald Nelson, Timothy S. Thomas, and Lindiwe Majele Sibanda, eds. 2013. Southern African Agriculture and Climate Change: A Comprehensive Analysis. IFPRI Research Monograph. Washington: International Food Policy Research Institute. Available at http://www.ifpri.org/publication/southern-african-agriculture-and-climate-change.

Hammond, J., et al. 2016. The Rural Household Multi-Indicator Survey (RHoMIS) for rapid characterisation of households to inform climate smart agriculture interventions: Description and applications in East Africa and Central America. Agricultural Systems (In press) http://dx.doi.org/10.1016/j.agsy.2016.05.003

Havlík, P., H. Valin, M. Herrero, M. Obersteiner, E. Schmid, M. C. Rufino, A. Mosnier, P. K. Thornton, H. Böttcher, R. T. Conant, S. Frank, S. Fritz, S. Fuss, F. Kraxner and A. Notenbaert. 2014. Reference scenario 2016 - LULUCF modelling methodology 24 "Climate change mitigation through livestock system transitions." Proceedings of the National Academy of Sciences 111(10): 3709-3714

Headey DD, 2013. Developmental drivers of nutritional change: a cross-country analysis. World Development 42, 76-88.

Herrero M., González-Estrada E., Thornton P.K. and Hoogenboom G. 2005 IMPACT: Integrated Modelling Platform for Mixed Animal-Crop Systems; version 1.1. Edited by ILRI (International Livestock Research Institute), Nairobi, Kenya. 130 pages.

HLPE. 2012. Food security and climate change. Roma: A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.

ILRI. n.d. ILRI Tools Portal. International Livestock Research Institute. Available online: http://data.ilri.org/tools/dataset/impactlite

IFPRI. 2015. Global Nutrition Report: Actions and accountability to advance nutrition and sustainable development. International Food Policy Research Institute, Washington, DC

IPCC. 2014. Cambio Climático 2014: Informe de Síntesis. Contribución de los grupos de trabajo I, II y III al Quinto Informe de Evaluación del Grupo Intergubernamental de Expertos sobre el Cambio Climático. Ginebra: IPCC.

IPCC. 2012: Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19.

Jalloh, Abdulai, Gerald C. Nelson, Timothy S. Thomas, Robert Zougmoré, and Harold Roy-Macauley, eds. 2013. West African Agriculture and Climate Change: A Comprehensive Analysis. IFPRI Research Monograph. Washington: International Food Policy Research Institute. Available at: http://www.ifpri.org/publication/west-african-agriculture-and-climate-change.

Jost C et al. 2016. Understanding gender dimensions of agriculture and climate change in smallholder farming communities. Climate and Development 8(2): 133–144

Jost, C; Ferdous, N; Spicer, TD. 2014. Caja de herramientas de género e inclusión; investigación participativa sobre cambio climático y agricultura. Programa de Investigación de CGIAR en Cambio Climático, Agricultura y Seguridad Alimentaria (CCAFS), CARE International y Centro Mundial Agroforestal (ICRAF). Copenhage, Dinamarcap.

Krishnamurthy, K., Lewis, K., Choularton, R. n.d. Climate impacts on food security and nutrition: A review of existing knowledge. World Food Programme.

Laborde, D., Tokgoz, S., Torero, M., 2013. Long-term drivers of food and nutrition security. FOODSECURE Working Paper No. 6.

León, A., Martínez, R., Espíndola, E., Schejtman, A. 2004. Pobreza, hambre y seguridad alimentaria en Centroamérica y Panamá. Santiago de Chile: Organización de las Naciones Unidas.

Lipper L, Thornton PK, Campbell B, Baedeker T, Braimoh A, Bwalya M, Caron P, Cattaneo A, Garrity D, Henry K, Hottle R, Jackson L, Jarvis A, Kossam F, Mann W, McCarthy N, Meybeck A, Neufeldt H, Remington T, Sen PT, Sessa R, Shula R, Tibu A, Torquebiau EF. 2014. Climate smart agriculture for food security. Nature Climate Change 4, 1068-1072.

Magrin, G.O., J.A. Marengo, J.-P. Boulanger, M.S. Buckeridge, E. Castellanos, G. Poveda, F.R. Scarano, and S. Vicuña, 2014: Central and South America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panelon Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1499-1566.

Martínez, R., Palma, A. (2014). Seguridad alimentaria y nutricional en cuatro países andinos: Una propuesta de seguimiento y análisis. Santiago: Naciones Unidas.

MacCalla, A., Revoredo, C. 2001. Prospects for global food security: a critical appraisal of past projections and predictions. International Food Policy Research Institute. Brief 71.

Misselhorn, A., Aggarwal, P., Ericksen, P., Gregory, P., Phathanothai, L.H, Ingram, J. And Wiebe, K. 2012. A vision for attaining food security. Current Opinion in Environmental Sustainability, 4, 7–17.

Mogelgaard, K., Darden, M., & Zaino, C. (2015). Climate change adaptation and population dynamics in Latin America and the Caribbean. Wilson Center. United States Agency for International Development.

Momsen JH. 2004. Gender and development. London. Routledge

Müller, C., Robertson, R. 2014. Projecting future crop productivity for global economic modeling. Agricultural Economics. Volume 45, Issue 1 Pages 37–50.

Naab, J.B. Koranteng, H. 2012. Gender and Climate Change Research Results: Jirapa, Ghana Working Paper No. 17. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Nairobi, Kenya.

Necco, G. 2012. Impactos potenciales del cambio climático en la seguridad regional en América Latina. Friedrich Ebert Stiftung. Proyecto Regional de Energía y Clima. Programa de Cooperación en Seguridad Regional.

Nelson, G.C., Mensbrugghe, D., Ahammad, H., Blanc, E., Calvin, K., Hasegawa, T., Havlik, P., Heyhoe, E., Kyle, P., Lotze-Campen, H. and Lampe, M., 2014. Agriculture and climate change in global scenarios: why don't the models agree? Agricultural Economics 45, 85-101.

Nelson, G. C., H. Valin, R. D. Sands, P. Havlík, H. Ahammad, D. Deryng, J. Elliott, S. Fujimori, T. Hasegawa, E. Heyhoe, P. Kyle, M. von Lampe, H. Lotze-Campen, D. Mason D'Croz, H. van Meijl, D. van der Mensbrugghe, C. Müller, A. Popp, R. Robertson, S. Robinson, E. Schmid, C. Schmitz, A. Tabeau, and D. Willenbockel. 2013. "Climate Change Effects on Agriculture: Economic Responses to Biophysical Shocks." Proceedings of the National Academy of Sciences of the United States of America 111 (9): 3274–3279.

Nelson GC, Rosegrant MW, Palazzo A, Gray I, Ingersoll C, Robertson R, et al. 2010. Food Security, Farming, and Climate Change to 2050. Washington, DC: International Food Policy Research Institute.

Nelson G, Rosegrant MW, Koo J, Robertson R, Sulser T, Zhu T, et al. 2009. Climate Change: Impact on Agriculture and Costs of Adaptation. Washington, DC: International Food Policy Research Institute.

Nelson, S., Huyer, S. 2016. A Gender-responsive Approach to Climate-Smart Agriculture: Evidence and guidance for practitioners. Practice Brief. FAO. CCAFS. Available at: https://cgspace.cgiar.org/rest/bitstreams/74482/retrieve

Odongo, D. 2014. ImpactLite survey tool improves understanding of on-farm reality. Climate Change, Agriculture and Food Security. Available online: https://ccafs.cgiar.org/es/blog/impactlite-survey-tool-improves-understanding-farm-reality#.V9rNDyjhDcu

Palazzo A, Vervoort J, Havlik P, Mason-D'Croz D, Islam S. 2014. Simulating stakeholder-driven food and climate scenarios for policy development in Africa, Asia and Latin America: A multi-regional synthesis. CCAFS Working Paper no. 109. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

Purdon M 2014. The Comparative Turn in Climate Change Adaptation and Food Security Governance Research. CCAFS Working Paper no. 92. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available at: www.ccafs.cgiar.org

Ray DK, Mueller ND, West PC, Foley JA. 2013. Yield Trends Are Insufficient to Double Global Crop Production by 2050. PLoS ONE 8(6): e66428. doi:10.1371/journal.pone.0066428

Rippke, U., Ramirez-Villegas, J., Jarvis, A., Vermeulen, S.J. Parker, L., Mer, F., Diekkrüger, B., Challinor, A.J., Howden, M. 2016. Nature Climate Change 6, 605–609. doi:10.1038/nclimate2947

Robinson, Sherman; Mason d'Croz, Daniel; Islam, Shahnila; Sulser, Timothy B.; Robertson, Richard D.; Zhu, Tingju; Gueneau, Arthur; Pitois, Gauthier; and Rosegrant, Mark W. 2015. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model description for version 3. IFPRI Discussion Paper 1483. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129825

Rosegrant, M.W., R. Valmonte-Santos, T. Thomas, L. You, and C. Chiang. 2015. Climate Change, Food Security, and Socioeconomic Livelihood in Pacific Island Countries. Mandaluyong City, Philippines: Asian Development Bank and International Food Policy Research Institute. Available online:http://www.adb.org/sites/default/files/publication/175046/climate-change-food-security-pacific.pdf.

Rosegrant M W, Fernandez M, Sinha A, Alder J, Ahammad H, de Fraiture C, Eickhout B, Fonseca J, Huang J, Koyama O, Omezzine A M, Pingali P, Ramirez R, Ringler C, Robinson S, Thornton P, van Vuuren D, Yana-Shapiro H, Ebi K, Kruska R, Munjal P, Narrod C, Ray S, Sulser T, Tamagno C, van Oorschot M and Zhu T. 2009. Looking into the future for agriculture and AKST (Agricultural Knowledge Science and Technology). Chapter 5 (pp 307-376) in Agriculture at a Crossroads (eds. B D McIntyre, H R Herren, J Wakhungu, R T Watson), Island Press, Washington DC.

Rosegrant, Mark W., Ximing Cai, Sarah A. Cline. 2002. World water and food to 2025: Dealing with Scarcity. International Food Policy Research Institute. ISBN 0-89629-646-

Rosegrant, M. W., M. Agcaoili-Sombilla, and N. D. Perez. 1995. Global Food Projections to 2020: Implications for Investment. Food, Agriculture, and the Environment Discussion Paper 5. Washington, DC: International Food Policy Research Institute. www.ifpri.org/sites/default/files/publications/vp5.pdf.

Rosenzweig, C., J. Elliott, D. Deryng, A. C. Ruane, C. Müller, A. Arneth, K. J. Boote, C. Folberth, M. Glotter, N. Khabarov, K. Neumann, F. Piontek, T. A. M. Pugh, E. Schmid, E. Stehfest, H. Yang, and J. W. Jones. 2014. "Assessing Agricultural Risks of Climate Change in the 21st Century in a Global Gridded Crop Model Intercomparison." Proceedings of the National Academy of Sciences, published ahead of print December 16, 2013, doi:10.1073/pnas.1222463110.

Rosenzweig, C. and Parry, M.L. 1994. Potential Impacts of Climate Change on World Food Supply. Nature 367:133–138. Disponible en línea en: t http://pubs.giss.nasa.gov/abs/ro05500b.html

.

Rosenzweig, C., Parry, M.L., Fischer, G. and Frohberg, K. 1993. Climate Change and World Food Supply. Research report no. 3. Oxford, UK, University of Oxford Environmental Change Unit.

Rutten M, 2013. What economic theory tells us about the impacts of reducing food losses and/or waste: implications for research, policy and practice? Agriculture & Food Security 2:13, DOI: 10.1186/2048-7010-2-13

Rufino, M.C., Quiros, C., Teufel, N., Douxchamps, S. Silvestri, S., Mango, J., Moussa, A.S., Herrero, M. 2012. Household Characterization Survey- IMPACTlite TRaining Manual. Climate Change, Agriculture and Food Security (CCAFS).

Rufino MC, Quiros C, Boureima M, Desta S, Douxchamps S, Herrero M, Kiplimo J, Lamissa D, Joash M, Moussa AS, Naab J, Ndour Y, Sayula G, Silvestri S, Singh D, Teufel N, Wanyama I. 2012. Developing generic tools for characterizing agricultural systems for climate and global change studies (IMPACTlite-phase 2). CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen

Samaniego, J. (2009). Cambio climático y desarrollo en América Latina y el Caribe: Una reseña. Santiago de Chile: Comisión Económica para América Latina y el Caribe (CEPAL). Sociedad Alemana de Cooperación Técnica (GTZ). Naciones Unidas.

Schaldach, R., Wimmer, F., Koch, J., Volland, J., Geißler, K. and Köchy, M., 2013. Model-based analysis of the environmental impacts of grazing management on Eastern Mediterranean ecosystems in Jordan. Journal of environmental management, 127, pp. S84-S95.

Scholes RJ, Palm CA, Hickman JE. 2014. Agriculture and climate change mitigation in the developing world. CCAFS Working Paper No. 61. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Scott, G., Rosegrant, W., Ringler, C. 2000. Global Projections for Root and Tuber Crops to the Year 2020. Food Policy 25 (2000) 561-597.

SDSN. 2015. Sustainable Developmnet Solutions Network. United Nation. Disponible en línea en: http://unsdsn.org/

Silvestri, S., Douxchamps., S., Teufel, N., Quiros, C., Singh, D., Ndungu, A. 2014. Data Quality Summary: CCAFS Detail Household Characterization Survey- Impact Lite Survey. Climate Change, Agriculture and Food Security.

Silvestri S, Rufino MC, Quiros C, Douxchamps S, Teufel N, Singh D, Mutie I, Ndiwa N, Ndungu A, Kiplimo J, Van Wijk MT, Herrero M. 2014. ImpactLite surveys. CCAFS, Harvard Dataverse Network, Cambridge.

Smith, P. et al. 2013. How much land-based greenhouse gas mitigation can be achieved without compromising food security and environmental goals? Global Change biology. DOI: 10.1111/gcb.12160

Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H.C.J., Gollin, D., Rayner, M., Ballon, P. and Scarborough, P., 2016. Global and regional health effects of future food production under climate change: a modelling study. The Lancet, 387(10031), pp.1937-1946.

Sraboni E., Malapit, H.J., Quisumbing A.R.,Ahmed, A.U. 2014. Women's Empowerment in Agriculture: What Role for Food Security in Bangladesh? World Development Vol. 61, pp. 11–52.

Sulser, T.B., Nestorova, B., Rosegrant, M.W. et al. 2011. The future role of agriculture in the Arab region's food security. Food Sec 3: 23. doi:10.1007/s12571-010-0100-

Swaminathan, M. S., & Kesavan, P. C. (2012). Agricultural Research in an Era of Climate Change. Agricultural Research 1 (1): 3-11, doi:10.1007/s40003-011-0009-z.

Takle, E. S., D. Gustafson, R. Beachy, G. C. Nelson, D. Mason-D'Croz, and A. Palazzo. 2013. "US Food Security and Climate Change: Agricultural Futures." Economics: The Open-access, Open-assessment E-journal 7 (2013-34). Accessed October 20, 2015. http://dx.doi.org/10.5018/economics-ejournal.ja.2013-34.

Tirado MC, Hunnes D, Cohen MJ, Lartey A, 2015. Climate change and nutrition in Africa. Journal of Hunger & Environmental Nutrition 10, 22-46. DOI: 10.1080/19320248.2014.908447

Thomas, Timothy, Tin Ponlok, Ros Bansok, Thanakvaro De Lopez, Cathy Chiang, Nang Phirun, and Chhim Chhun. 2013b. "Cambodian Agriculture: Adaptation to Climate Change Impact", IFPRI Discussion Paper 01285 (August). Washington: IFPRI. Available at http://www.ifpri.org/sites/default/files/publications/ifpridp01285.pdf.

Thomas, Timothy, Khandaker Mainuddin, Catherine Chiang, Aminur Rahman, Anwarul Haque, Nazria Islam, Saad Quasem, and Yan Sun. 2013a. "Agriculture and Adaptation in Bangladesh: Current and Projected Impacts of Climate Change", IFPRI Discussion Paper 01281 (July). Washington: IFPRI. Available at http://www.ifpri.org/sites/default/files/publications/ifpridp01281.pdf.

Thomson, Madeleine; Fanzo, Jessica. 2015. Climate change and nutrition. In Global Nutrition Report 2015: Actions and accountability to advance nutrition and sustainable development. Chapter 6. Pp. 74-84. Washington, DC: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129450

Thornton, P., Ericksen, P., Herrero, M., Challinor, A.J. 2014. Climate variability and vulnerability to climate change: a review. Global Change Biology. 20, 3313-3328. DOI: 10.1111/gcb.12581

Van Dijk, M., Gramberger, M., Laborde, D., Mandryk, M., Shutes, L., Stehfest, E., Valin, H., Zellmer, K., 2015. Scenarios to explore global food security up to 2050: Development process, storylines and quantification of drivers. International conference of agricultural economists (ICAE), Universitá degli Studi di Milano.

Vergara, W., Ríos, A., Trapido, P., & Malarín, H. 2014. Agricultura y clima futuro en América Latina y el Caribe: Impactos sistémicos y posibles respuestas. Banco Interamericano de Desarrollo.

Vermeulen, S.J., Challinor, A.J., Thornton, P.K., Campbell, B.M., Eriyagama, N., Vervoort, J.M., Kinyangi, J., Jarvis, A., La¨derach, P., Ramirez-Villegas, J., Nicklin, K.J., Hawkins, E., Smith, D.R., 2013. Addressing uncertainty in adaptation planning for agriculture. Proc. Natl. Acad. Sci. U. S. A. 110, 8357–8362.

Vermeulen S, Zougmore R, Wollenberg E, Thornton P, Nelson G, Kristjanson P, Kinyangi J, Jarvis A, Hansen J, Challinor A, Campbell B, 2012. Climate change, agriculture and food security: a global partnership to link research and action for low-income agricultural producers and consumers. Current Opinion in Environmental Sustainability 4(1), 128-133.

Vervoort, J.M., et al., 2014. Challenges to scenario-guided adaptive action on food security under climate change. Global Environmental Change, http://dx.doi.org/10.1016/j.gloenvcha.2014.03.00

Waithaka, Michael, Gerald Nelson, Timothy S. Thomas, and Miriam Kyotalimye, eds. 2013. East African Agriculture and Climate Change: A Comprehensive Analysis. IFPRI Research Monograph. Washington: International Food Policy Research Institute. Available at http://www.ifpri.org/publication/east-african-agriculture-and-climate-change.

Wollenberg, L., Richards, M., HAvliok, P., Smith, P., Tubiello, F., Carte, S., Herold, M. 2015. Will sustainable intensification help us avoid exceeding 2°C. Global Scienci Conference March 16-18, 2015. Le Corum, Montpellier France.

Woltjer, G.B. and M.H. Kuiper, 2014. The MAGNET Model: Module description. Wageningen, LEI Wageningen UR (University & Research centre), LEI Report 14-057. 146 p

World Bank. 2009. World Development Report 2009: Reshaping Economic Geography. World Bank. https://openknowledge.worldbank.org/handle/10986/5991 License: CC BY 3.0 IGO

World Bank, 2006. Repositioning Nutrition as Central to Development: A Strategy for Large-Scale Action. Overview. Washington DC.

Ye, L., H. Tang, W. Wu, P. Yang, G. C. Nelson, D. Mason-D'Croz, and A. Palazzo. 2014. "Chinese Food Security and Climate Change: Agriculture Future." Economics: The Open-access, Open-assessment E-journal 8 (2104-1). Accessed October 20, 2015.

Yasabu, S. 2013. African RISING uses IMPACT-Lite Survey tool to document baseline data in Ethiopia. Africa RISING: Research in sustainable intensification for the next generation. Available at: https://africa-rising.net/2013/09/08/impactlite/ .

You, L., S. Wood, U. Wood–Sichra, W. Wu. 2014. "Generating Global Crop Distribution Maps: From Census to Grid." Agricultural Systems 127 (May): 53–60.

RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic initiative of CGIAR and Future Earth, led by the International Center for Tropical Agriculture (CIAT). CCAFS is the world's most comprehensive global research program to examine and address the critical interactions between climate change, agriculture and food security.

For more information, visit www.ccafs.cgiar.org

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

CCAFS is led by:

Strategic partner:

Research supported by: