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Theoretical Conception of Climate-Smart Agriculture

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Abstract

In this paper, I explored the various components and conceptual underpinnings of climate smart agriculture to develop a conceptual framework to better understand climate smart agriculture. Furthermore, I proposed a new definition of "climate smart agriculture" based on the various components of the concept and the need for trade-offs and synergies. "Climate smart agriculture technologies and management practices" was also defined based on pillar three of climate smart agriculture as a necessary condition. I argue that since the buzzword "climate smart" has strictly a climate focus, the concept of climate smart agriculture resonates more on GHG emission mitigation. I however posit that a more concise definition of the climate smartness of agricultural production systems will require empirical measurement of some aspects of the concept. Since climate smart agriculture is defined along three pillars (productivity increases, building resilience and adapting, and GHG emission reduction), key concepts such as productivity, resilience, vulnerability and carbon sequestration provide indicators for future empirical measurements of the climate smart agriculture concept.

Keywords: Climate, agriculture, policies, institutions, theory, concept
JEL classification:

1 Introduction

In tropical regions, crops, livestock and fisheries are most affected by current climate change. In parallel, tropical regions coincide with areas of current low food security and a high prevalence of poverty. Smallholder farmers in such regions have also been observed to have a low resilience to climate shocks because they often have fewer resources and less access to education, innovation and financial services or safety nets. At the same time, having fewer livelihood options and being too specialize leads to less resilience to climate shock (Campbell et al., 2014). Climate changes compounds the existing challenges in improving crop productivity and welfare for farm households by affecting the mean and variability of weather conditions and the frequency of extreme weather events (Mullins et al., 2018). Reducing therefore the vulnerability of smallholders and agricultural systems to climate change and strengthening adaptive capacities are therefore important priorities to protect and improve the livelihoods of the poor and allow agriculture to fully play its role in ensuring food security (Lipper et al., 2018).

This where the concept of Climate Smart Agriculture (CSA) comes to focus. In the year 2009, the Food and Agriculture Organization (FAO) of the United Nations launched the concept of Climate Smart Agriculture (CSA) to draw attention to linkages between achieving food security and combating climate change through agricultural development, and the opportunities for attaining large synergies in doing so (Lipper et al., 2018). As a concept, CSA is therefore geared towards guiding the management of agriculture in the era of climate change (Lipper and Zilberman, 2018) and achieving food security, while also mitigating climate change and contributing to other development goals (Verhagen et al., 2014). CSA as an approach therefore helps farmers to reduce vulnerability, increase adaptive capacity and to better cope with ex-post risk (Lipper et al., 2018). In this paper, I develop a conceptual framework and definition of CSA. I do this by reviewing the empirical literature and applications of the concept of climate smart agriculture. The paper is organized into four parts. In the first part, I define and explore all the components of Climate Smart Agriculture and develop a framework to understand the concept. In the second part, I highlight the conceptual and theoretical underpinnings of Climate Smart Agriculture. In the third part, I propose and operationalize a new definition of Climate Smart Agriculture and some challenges it presents for empirical measurements. In part four, I conclude and present some future outlook.

2 Components of Climate Smart Agriculture

2.1 What is Climate Smart Agriculture (CSA)?

The climate-smart agriculture (CSA) concept is gaining considerable traction at international and national levels to meet the challenges of addressing agricultural planning under climate change. Several definitions of the concept CSA have emerged from the various empirical literature and also from international development organizations. The World Bank[1] for instance defines CSA as an integrated approach to managing landscapes, cropland, livestock, forests and fisheries that address the interlinked challenges of food security and climate change. Lipper et al. (2014), also defined CSA as an "approach for transforming and reorienting agricultural development under the new realities of climate change". Sustainable Food Lab[2] also defines CSA as an "approach for transforming agriculture under the new realities of climate change". Verhagen et al. (2014) and CCAFS[3] define CSA as an "integrated approach to achieve food security in the face of climate change, while also mitigating climate change and contribute to other development goals".

Lipper and Zilberman (2018) however noted that the term "CSA" was widely adopted before the development of a formal conceptual framework and tools to implement the approach, leading to considerable variation in meanings applied to the term, hence some controversies in the use of the term. At the same time, the aforementioned authors argue that no specific guidance was provided by the FAO on how to define a CSA practice, or prioritize amongst objectives, to develop site specific CSA solutions. Lipper et al. (2018) also reports of the presence of a fair amount of confusion regarding the concept of CSA and its theoretical underpinning. Verhagen et al. (2014), also argues that CSA as concept is still being elaborated, in concept as well as in application. Two of the key concepts that comes up with the CSA concept is resilience and vulnerability and according to Lipper et al. (2018) there is the need to define and operationalize the concept of resilience and adaptive capacity in the context of agricultural growth for food security which is an embedded component of the CSA concept.

Lipper and Zilberman (2018) also argue of a missing clear conceptual framing of the link between sustainable agriculture and CSA due to the complexity of tying together the three main objectives of CSA. Subsequently, the lack of a clear methodology together with a rapid uptake of the concept has resulted in considerably variability in the use of the term and confusion, which in turn has been a major source of controversy around the concept (Lipper and Zilberman, 2018). In addition, Lipper et al. (2018) argues that as a concept the empirical evidence base to support country-level implementation strategies is lacking. Furthermore, the lack of clear principles by which to define a practice or technology as

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[1] http://www.worldbank.org/en/topic/climate-smart-agriculture, accessed on 20.07.2018

[2] https://sustainablefoodlab.org/initiatives/climate-smart-agriculture/, accessed on 20.07.2018

[3] https://ccafs.cgiar.org/climate-smart-agriculture-0#.V5S9aEt97IU, accessed on 21.07.2016

CSA has thus led to a general concern that the CSA concept and branding could to be used to advance non-sustainable and non-desirable forms of agricultural development (Lipper and Zilberman, 2018). This debate, Lipper and Zilberman (2018) argues has been basically driven by a misguided notion that CSA is essentially a proposal for a "new type of agricultural practice, giving rise to concerns directly related to ongoing and fierce debates about technologies for sustainable agriculture". Kaczan et al. (2013) argues that CSA is largely defined by its intended out-comes rather than by a set of specific practices or approaches.

However, in practice, the CSA concept involves integrating the need for adaptation and the potential for mitigation into the planning and implementation of agricultural policies, planning, and investments. The point of departure for the CSA concept is the emphasis on food security and poverty reduction as the priority in developing countries through enhanced capacity of their agri-food sectors and institutional and technological innovations (Lipper et al., 2018). Lipper and Zilberman (2018), also suggests that CSA does not attempt to provide a prescription to any user of the approach for resolving the discourse between agriculture and climate change, but rather a tool to identify locally appropriate solutions to managing agriculture for sustainable development and food security under climate change. Regardless of the definition used, the concept of CSA calls for integration of the need for adaptation and the possibility of mitigation in agricultural growth strategies to support food security (Lipper et al., 2018). The CSA concept calls for meeting three key objectives or pillars: i) sustainably increasing food security through increases in productivity and incomes, ii) building resilience and adapting to climate change (adaptation), and iii) reducing greenhouse gas emissions compared to a business as usual or baseline scenario (mitigation). CSA objectives is therefore to deliver worldwide relevant principles on managing agriculture for food security under climate change (Lipper and Zilberman, 2018).

Furthermore irrespective of the definition of CSA used, Verhagen et al. (2014) identifies three elements of the concept that stands out. As a concept, CSA is conceived as i) a process, ii) highly context specific and iii) involves more than food security and increasing agricultural production (*ibid*). Another important thing worth noting is that CSA as a concept goes beyond agricultural practices and technologies to include enabling policies and institutions as well as identification of financing mechanisms (FAO, 2013). The integration and coordination of relevant policy instruments and institutional arrangements helps to develop appropriate institutional and governance instruments to disseminate information, ensure broad participation and harmonize policies that helps in scaling up climate-smart technologies and practices. On the other hand, innovative financing mechanisms that link and blend climate and agricultural finance from public and private sectors are a key means for implementation CSA (FAO, 2013).

CSA also involves coordination across agricultural sectors such as crops, livestock, forestry and fisheries as well as other sectors, such as with energy and water sector development to capitalize on potential synergies, reduce trade-offs and optimize the use of natural resources and ecosystem services (FAO, 2013). The CSA concept and methods Lipper and Zilberman (2018) argues were developed by international technical agencies[4] to provide a framework for formulating and taking actions to respond to climate change in agriculture by encompassing a wide spectrum of political and economic approaches to managing agriculture. CSA in the nutshell involves technological, institutional and policy solutions which have wide-reaching implications and covers a broad spectrum of sustainable development objectives. To this end, Zilberman (2018) described CSA as a framework for developing decision support systems at the farm and policy level with the aim of providing principles to identify technologies, management tools, and policies that will enable farmers to adapt to challenges of climate change while maintaining and improving societal well-being. CSA can therefore not work in isolation and therefore requires some external supports and inputs that herein act as "enabling or supporting" factors[5].

Based on the empirical literature on climate smart agriculture, I developed and described a conceptual framework defining CSA and the relevant inter-linkages in figure 1. In the framework, the large dark green triangle represents the technological components of CSA, containing the various climate smart agricultural technologies and management practices that cuts across the various agricultural sectors (crop, animal production, fisheries/aquaculture and forestry). These technological components, which may be applied complementarily, work towards achieving the three pillars (shown in the three lime green intersecting circles) of CSA - sustainably increases in productivity and income (pillar I), building resilience and adapting to climate change (pillar II) and GHG emission reduction (pillar III). The likely synergies and trade-offs with the three pillars of CSA are shown with the red intersecting lines. The sizes of the intersecting areas among the various pillars will vary depending on the technology sets chosen, the location and socio-economic context. The sizes will also vary across space and time due to changes in climate and socio-economic variables. In addition, the level of trade-offs and synergies achieved is directly influenced by institutional, policy and financing factors which in the nutshell serve as important enabling or supporting factors of CSA.

The enabling or supporting factors are of the essence because they are development tools for optimizing social welfare in general. For instance, adapting and mitigating against climate change implies increasing farmers' resilience, conservation and protection of natural resources, and increasing resource use efficiency. Sustainably increasing productivity and incomes also implies that the livelihoods of rural farm households are protected and improved. The adoption of useful CSA technologies and management practices in devel-

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[4] FAO, World Bank, and the Climate Change and Food Security Programme of the CGIAR

[5] These factors in the nutshell can also been seen as nudging, stimulating or conditioning factors

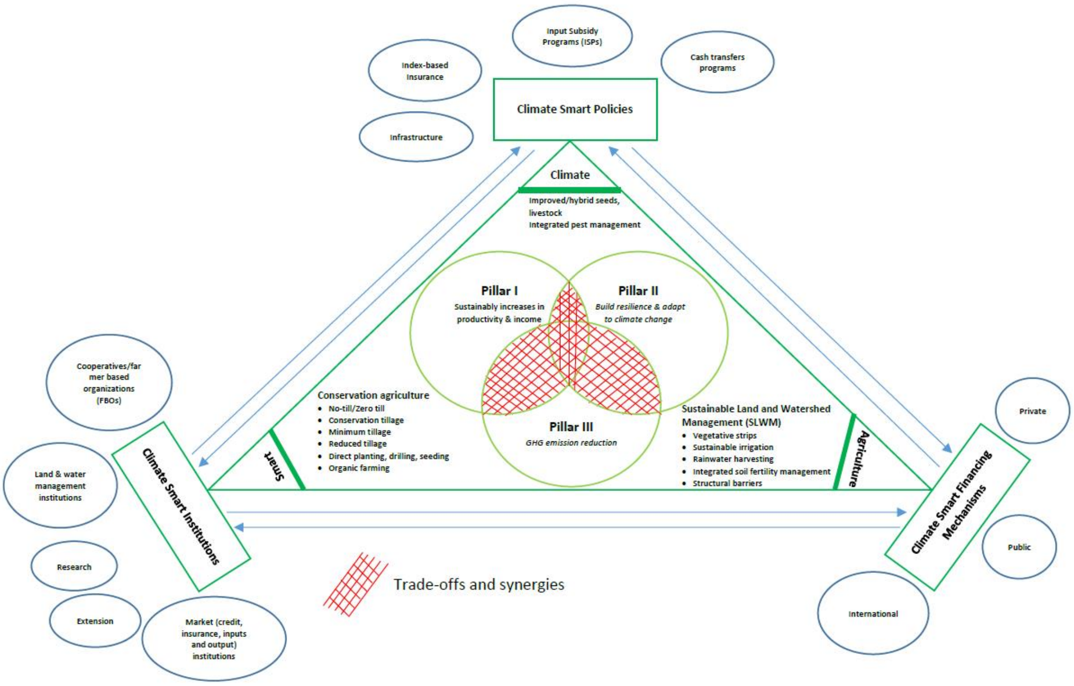

Figure 1: Climate smart agriculture (CSA) conceptual framework

oping regions of the world is typically constrained by lack of access to markets (inputs and outputs), as well as financial constraints, poor infrastructure and access to information. These constraints do not only impede on the adoption of CSA technologies and management practices but also on development and resilience of farmers in the midst of climatic risks. In the nutshell, climate smart[6] policies, institutions and financing mechanisms serve as enabling and supporting factors that facilitates the planning and implementation of CSA programs and also the adoption of CSA technologies and management practices by farmers. These "enabling or supporting" factors are in discussed in further details in the succeeding subsections.

2.2 Climate smart policies

Climate smart policies (CSP) are meant to emphasize incentives and capabilities to encourage improved decision-making, enhance resilience and adaptive capacity to changing agro-climatic conditions and also the adoption of best feasible technologies, improve input use, and post-harvest practices at the farm-level (Zilberman, 2018). Climate smart policies do not only provide incentives to farmers but to also potentially develop mechanisms

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[6] The buzzword "climate smart" means incorporating projections of future impacts of climate change in making informed decisions. So a climate smart policy for instance means that climatic impacts is considered in making informed policy decisions. Climate smart information means providing relevant information based on climatic data and projected future impacts to help make informed decisions. Same analogy for climate smart institutions, programs, financing etc.

to monitor climate and other conditions, assess situations, and to respond to changing realities (Zilberman, 2018). Some of the climate smart policy scopes that can potentially amplify CSA adoption includes: cash transfer programmes, subsidized index-based Insurance (livestock and crops), and Input Subsidy Programs (ISPs).

These climate smart policies just as CSA agriculture are nothing new and with no intentions of reinventing the wheel. In the last couple of decades, these development policies have been used as safety-net programs in developing countries with the aim of reducing poverty and increasing food security, and in most cases the targeting focused on economic vulnerability rather than climate vulnerability (Caron et al., 2018). However, these policies have been observed to be effective in managing climate risk and potentially mitigating the effects of climate change. Climate smart policies can also support CSA by facilitating improved and better access and a move towards higher liberalization of markets (credit, insurance, inputs and outputs), provision of better infrastructure and an improvement in the investment climate for post-harvest processing (Caron et al., 2018; Zilberman, 2018). Climate smart policies promoting secure land tenure regimes builds incentives from the bottom-up so that farmers are more willing to invest in long term profitable CSA technologies such as soil, land and water management and agroforestry (Caron et al., 2018). This is also important in helping farmers to deal with credit constraints and ensure that they can have access to other CSA technologies.

Climate smart policies together with institutional environments also directly influence trade-offs achieved between the CSA objectives. Lipper and Zilberman (2018), provides an example of this influence. They suggested that sustainable land management techniques such as land restoration or agroforestry takes years to generate benefits, require up-front investments and also involves reductions in income during the initial phase. However, in a longer time frame such land management techniques can result in higher economic, environmental and social benefits. In the initial phases there are significant trade-offs between them and hence the need to effectively induce transformative change of adopters by providing the necessary incentives and support. Input Subsidy Programs (ISPs) despite its unsustainability and being riddled with problems such as inefficient resource allocation by farmers, poor targeting at the farmer level and hence more influential and politically connected farmers benefiting more, moral hazards and corruption (Caron et al., 2018) are also very important instruments to support CSA. In short-term situations whereby learning-by-doing is needed, input subsidies can be an important tool in encouraging the adoption of CSA technologies and management practices if well targeted (Zilberman, 2018). ISP are also relevant for increasing resource poor smallholder farmers' access to improved agricultural inputs (Caron et al., 2018). Index insurance can also serve as an important tool for increasing resilience in smallholder agriculture livelihoods. Caron et al. (2018) argue that index insurance can also serve as an important tool to help farmers better manage climate risk.

2.3 Climate smart institutions

Lipper and Zilberman (2018), argues that a major push of CSA is the improvement of climate change and agricultural governance through better coordination and institutional strengthening. Institutional environments by themselves have a significant impact on farmers incentives and ability to invest in agriculture practices and to adapt to climate change (McCarthy et al., 2018). Climate smart and innovative institutional models are important in helping support opportunities for small and marginal farmers. Institutions relating to land and water management, group or cooperative approach for inputs and marketing and value chains and supermarkets are very important as enabling factors in helping agriculture and therefore farmers access inputs in a timely fashion, and selling their outputs. They are particularly important in enhancing productivity, sustainability and incomes of small holding agriculture. Zilberman et al. (2018) argues that institutional innovations at the macro and farm system levels such as "climate smart" extension programs, full spatial coordination among farmers to deal with broader externalities, institutional management of water resources, insurance regulations, social safety nets etc. are relevant in supporting the adoption of CSA technologies and management practices.

Caron et al. (2018) also identifies four key areas of institutional support needed to support farmers to adapt to climate change. These institutional support areas include: enabling smallholders farmer groups and cooperatives access high-value markets; provision of a wider range of viable and attractive financial and risk management tools; increasing information dissemination needed for smallholders to increase knowledge and technical skills to take advantage of adaptation strategies (herein CSA technologies and management practices) and lastly ensuring that the livelihoods of smallholders are protected in the aftermath of severe weather events through social safety net programs. Interactions between policies and institutions are also very important in helping farmers' better cope with climate change. For example, moves towards open voucher systems under ISPs for instance can induce greater private sector participation and hold the potential to support the development of profitable and more sustainable input distribution systems to provide more heat, drought and saline-tolerant seed types to farmers (Lipper et al., 2018). Involving the private sector increases the input sourcing portfolio of farmers and this can help farmers to focus on farming without worrying about market shortages.

As pointed out earlier, institutions relating to land and water management will be very important in helping farmers' better adapt to climate change and several empirical literature on adaptation suggests that water management is going to be a key issue for climate change adaptation and increasing resilience in agriculture. However as argued by Caron et al. (2018), this can only be successful and an essential adaptation strategy if substantial public investments in physical infrastructure are made, but also the need for improved institutional capacity (Zilberman, 2018). Adaptation capacity of agriculture and hence smallholder farmers to climate change begins with investments in and incentives for innovation. Public investments in infrastructure such as rural roads, market places, storage facilities and related services will be essential in reducing transactions costs faced by poor households. Developing such infrastructure and supply chains requires strong involvement of the private sector, sometimes in partnership with the public sector, within an improved policy environment (Zilberman, 2018).

Private and public sector partnerships in this sense will be important in providing some of these investments and also in expanding and improving the supply chains of credit and farm-level inputs and outputs. Institutions related to knowledge and research are also key elements in enabling CSA. These are responsible for making the right technologies and information to farmers as well as the know-how in the use of these technologies. In this regards, a bottom-up approach has been suggested as highly relevant to streamline information flow from farmers to researchers and vice versa. Factors also pertaining to conducive enabling policy environments and public investment, assurance of peace and security, stable macro-economic conditions, functioning markets and appropriate incentives can act as an important stimuli in making agriculture climate smart (Ehui and Pender, 2005; Westermann et al., 2015).

As the world climate system changes, local weather patterns will become more unpredictable. Many parts of the global tropics, is projected to have highly variable rainfall, and many smallholders will inevitably experience livestock loss and crop yield reductions if not total crop failure. By 2020, the IPCC (2007) estimates that in some countries, yields from rain-fed agriculture could be reduced by up to 50% due to climate change. These reductions in yield is going to be severe in tropical regions, which already coincide with areas of current low food security and a high prevalence of poverty. Weather volatility is particularly increasing and hence the need to help farmers build resilience against climatic shocks. In sub-Saharan Africa for instance, rainfall variability is high with the frequency of hydrological shocks is increasing (Zseleczky and Yosef, 2014). Furthermore, farmers have limited access to the information they need about specific farming practices and local climate conditions. Hence farmer's ability to adapt to climate change and be climate smart is especially affected by the information dissemination system and farmers ability to access weather forecasts and longer-term climate predictions and to incorporate that information into adaptation and coping strategies (FAO, 2013; McCarthy et al., 2018). Rainfed agriculture systems are particularly vulnerable to weather variability both between seasons and within a season. Hence reducing farmers' vulnerability to current climate risk is one of the most appropriate entry points into future adaptation, given that climate change may most often be experienced as changes in the frequency and severity of extreme events (Thornton et al., 2018). Empirical studies such as the one by Sandmo (1971); Dixit and Pindyck (1994, 2004) also suggests that uncertainty patterns and levels delay the optimal timing of investment by economic agents.

In the context of agriculture, uncertainty of weather patterns means that farmers value additional information and are willing to wait some time for more information, which can lead to significant delays in investments and this can compound risk-averse farmer's disincentives to invest CSA technologies and management practices. Uncertainty associated with rainfall variability in this regards can be reduced through the provision and use of weather information and climate advisory services, enabling smallholders to better manage risks and take advantage of favourable climate conditions when they occur (Hansen et al., 2011). Farmers access to available weather forecasting information serve as an early detector of growing conditions and this can help them to adjust planting seasons by simply making changes in planting dates and this can have profound impacts on farm productivity (Thornton et al., 2018).

Basist et al. (2018) also argues that planting is one of the most important periods in crop production, hence wetness and temperature can be used to optimize planting decisions. Integrating agricultural advisory services, input markets with tailored climate services, which bring in new information to complement and extend farmers knowledge, can reduce climate uncertainty to empower smallholders to benefit from CSA technologies and management practices (CIAT, 2015). Thornton et al. (2018) argues that providing appropriate weather information with its associated advisory services can help smallholders make more informed decisions regarding the management of their crops and livestock, leading to increased productivity. Advisory services for farmers could be in the form of vouchers, which could be provided to farmer groups to source extension services from private sector providers. At the same time, the effective use of weather information may also contribute to farmers resilience by helping them better manage the negative impacts of weather-related risks in poor seasons while taking greater advantage of better than average seasons (Thornton et al., 2018). Rainfall or chemical input efficiency can be significantly increased through optimized timing and quantities of application if weather information is essential provided to farmers at the right time and form. Provision of weather information services can also be used as an educational and informational tool to assist farmers in their selection of crop types and varieties, resource allocation among crops, and selection and implementation of production practices and other adaptation or mitigation strategies. Providing early warning systems for disaster risk reduction, could also offer potential benefits to farmers.

Climate smart institutions could therefore potentially play a very important role in provision of climate smart services and solutions to farmers in the form of information. Climate services for smallholder farmers in the form of provision of more robust climate data to farmers will help them prepare and plan for climate change. Providing climate information and services reduces uncertainty and help farmers make better use of new seeds and technologies to support complex and context-specific decisions about farm labour and resource allocation (CIAT, 2015). For example, use of weather information by farmers may contribute to GHG emissions mitigation for instance through better matching of use fertilizer and other crop or pasture with prevailing weather conditions (Thornton et al., 2018). Institutional support and policies, advisories and climate information whether historical, monitored or predicted offers great potential to enable smallholder farmers to make informed decisions, better manage risk, take advantage of favourable climate conditions, and adapt to change (CCAFS[7]). Generating and disseminating climate relevant information will have the desired impact if the information is better tailored to farmer's needs. For instance if it is translated into a useful form via improved access, provided in a timely manner, meaningful and the climate information and knowledge provided is trustworthy.

2.4 Climate smart financing mechanisms

Reorienting agriculture in the midst of climate change, calls for the need of adaption and mitigation. The necessity to adapt to climate change and mitigate against GHG emissions in the near, medium and long term implies changes in agricultural investment needs from the farm scale up to the national and international levels (FAO, 2013). At the same time the FAO (2013) argues that climate change affect investment needs for agriculture through an already financing deficit in terms of development, adaptation and mitigation. Adaptation in particular entails additional costs being imposed on agricultural investments and this alters the projection of agricultural investment needs in terms of amount, timing and type of investment required (FAO, 2013). Furthermore, several mitigation efforts are synergistic with activities that promote agricultural growth having the potential to attract new sources of finance for sustainable agriculture (*ibid*).

A simple first step to identify potential overlaps between adaptation and development investments as well as potential maladaptive agricultural investments according to the FAO (2013) is through the screening of agricultural investment plans for their degree of "climate smartness". Furthermore, obtaining estimate of marginal abatement costs or the potential mitigation benefits that agricultural investment activities could generate, is an important tool for both for ranking investments as well as setting targets. Incorporating projected future impacts of climate change into today's investment planning it is essential for reducing vulnerability to the impacts of climate change and the costs of dealing with these impacts (FAO, 2013). At the same time, investments made in the agricultural sector is geared towards achieving multiple objectives, such as agricultural growth for food security, poverty reduction and economic development (FAO, 2013).

Recent studies suggests that public sector investments in agriculture in developing countries are lagging in areas where growth is essential for poverty reduction. Particularly in the case developing regions of the world especially sub-Saharan African and South

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[7] https://ccafs.cgiar.org/themes/climate-services-farmers

Asia, which are among the most vulnerable agricultural areas, there is a large deficit in investment resources. Public sector investments in agriculture are particularly lagging in these two regions (FAO, 2013). Nelson et al. (2009) estimate the negative impacts of climate change on crop productivity and on child malnutrition requires approximately US$ 3 billion and US$ 1.5 billion annually in additional productivity enhancing investments to counteract the negative impacts of climate change and maintain a baseline level of welfare in for sub-Saharan Africa and South Asia respectively. Investment to support sustainable agricultural growth in these regions is essential, as several studies (e.g. World Bank, 2007; de Janvry and Sadoulet, 2009) have shown that the most effective means of reducing poverty and food insecurity amongst poor households in agricultural-based economies is economic growth in the agricultural sector. According to the FAO (2013), agricultural growth for food security and poverty reduction is a key adaptation strategy that reduces vulnerability and increases the resilience of affected people. Investment is hence the engine for such growth, however the FAO (2013) argues the levels and composition of investment have not been adequate to stimulate needed growth, particularly in those regions where it is most important.

Reform of agricultural sectors the FAO (2013) argues need to incorporate climate change considerations ultimately through the restructuring of agricultural investments at the public, as well as private, and the national level. Furthermore, innovative financing mechanisms that link and blend climate and agricultural finance from public and private sectors are a key means for CSA implementation. The implementation of policies and institutional support programs described in the preceding sections requires financing. Hence, innovative financing mechanisms that link and blend climate and agricultural finance from public and private sectors are important means of funding CSA projects. Focusing public sector spending on essential public goods such as agricultural research and development, transport, telecommunication and ICTs, and human capital development allows the shift towards more sustainable and climate-smart sources of agricultural growth. Implementing and scaling up CSA, particularly will require investments in research and development of technologies and practices as well as extension. Investments in efficient input supply chains for instance will ensure the availability of inputs when they are needed by farmers in the quantities (FAO, 2013).

Public sector finance is also important in creating the necessary conditions and incentives for farmers to make needed investments. Farmers are by far the largest source of agricultural investment finance (FAO, 2012), particularly in the area of potential CSA technologies and management practices. However, access to credit is one of the key inhibiting factors of CSA adoption by farmers. At the same time when investing in these CSA technologies and management practices, farmers face the longest wait for positive returns implying the importance of long-term financing to food security and poverty reduction. For example, CSA technologies with high up-front investment costs are mostly the ones with a positive marginal abatement cost, hence implying the need for external finance to support farmers investing in them. The implications for public sector finance will hence be required to support credit or safety net programmes that can maintain farm income levels over periods required for such investments to bear fruits. Consideration of investments in an enabling environment that supports sustained adoption of improved practices, will thus be important in avoiding problems of dis-adoption after short-term project interventions (FAO, 2013).

Another aspect of the concept of CSA is seeking to identify opportunities to access climate-related financing and integrate it with traditional sources of agricultural investment finance (FAO, 2013). Nevertheless, international financing plays a crucial role in this transition and can act as a catalyst for the broader adoption of CSA practices by demonstrating the feasibility of CSA approaches, facilitating climate change main-streaming into national policy and legal frameworks, and promoting the creation and transfer of skills, knowledge and technologies (FAO, 2013).

In the nutshell as a concept, CSA provides a tool to identify locally appropriate solutions to managing agriculture for sustainable development and food security under climate change. These enabling or supporting factors (policies, institutions and financing mechanisms) of CSA therefore act as a climate management policy and provide the necessary incentives for farmers to engage in activities that meets the three pillars of CSA and as well provide overall social goods that reduce negative environmental externalities at the same time. Technology alone will not be sufficient in adapting agriculture to climate change; they need to be supported by instruments related to policies, institutions and finance. These factors together work to increase farm household resilience by reducing their exposure and sensitivity to climate change, and increasing adaptive capacity while at the same time achieving the three pillars of CSA. Attaining the three pillars of CSA requires some trade-offs to be made, the enabling and supporting factors help to increase synergies, and amplify these trade-offs. A general framework for assessing trade-offs and synergies of CSA has been provided by the FAO, along with several examples of sustainable land management practices and modern inputs (FAO, 2009). The effectiveness of these enabling or supporting factors highlighted in this section depends on specific climate, demographic, environmental, economic and institutional factors.

3 Conceptual and theoretical underpinnings of CSA

The Climate Smart Agriculture (CSA) concept was developed in order to address the complex issue of how to achieve sustainable agricultural growth for food security under climate change (FAO, 2009, 2010; Lipper et al., 2014). The conceptual foundations of CSA however draws upon theory and concepts from agricultural development, institutional and resource economics (Lipper et al., 2018). The evolution of climate change policy, which has been related to collective global actions to stabilize greenhouse gas (GHG) emissions has also been instrumental in CSA conceptualization. The establishment of the Clean Development Mechanism (CDM) under the Kyoto Protocol provided a basis for emissions reductions highly relevant to agricultural development in terms of sequestering carbon through improved soil management and forestry (McCarl and Schneider, 2001). Adaptation in the agriculture sector is given high priority, and mitigation from agriculture, including sequestration is also quite a prominent submissions in the intended nationally determined contributions (INDCs) of parties of the Conference of Parties to the UNFCCC. Recognition of the agricultural sector being key to climate change response, not only because of its high vulnerability to climate change effects, but also because it is a main contributor to the problem (Lipper and Zilberman, 2018) was instrumental in the conceptualization of CSA. According to Lipper and Zilberman (2018), the CSA approach was established in "response to limitations in the international climate policy arena in the understanding of agriculture's role in food security and its potential for capturing synergies between adaptation and mitigation".

An important foundation of CSA is the sustainable agriculture concept which is in itself part of the larger concept of sustainable development; a development strategy that aims to ensure that future generations would not be worse off compared to the present generation (WCED, 1987). Sustainable development in itself contains three key elements; economic, social, and environmental. Lipper and Zilberman (2018) emphasize that CSA as a concept integrates the specificities of climate change adaptation and mitigation into sustainable agricultural development policies, programs and investments. Hence CSA strategies and practices have conceptual links and adhere to the general principles that underpins sustainable agriculture processes and food systems such as; improvements in the efficiency of resource use, conservation, protection and enhancement of natural resources, protection and improvement of rural livelihoods, and responsible and effective governance mechanisms[8]. Additionally CSA also embeds the objectives of agricultural development of increasing food security through increases in productivity and incomes.

Lipper and Zilberman (2018), however argue that as a concept, CSA is not intended to provide a new set of sustainability principles, but rather a means of incorporating the specificities of adaptation and mitigation into sustainable agricultural development policies, programs and investments. CSA strategies and practices should therefore be in adherence to the principles that underpin sustainable agriculture and food systems such as (1) improving the efficiency of resource use, (2) conserving, protecting and enhancing natural resources, (3) protecting and improving rural livelihoods, (4) enhancing resilience of people, ecosystems and communities and (5) responsible and effective governance mechanisms. Additionally CSA underpins some concepts in resource economics

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[8] http://www.fao.org/sustainable-development-goals/overview/fao-and-the-post-2015-development-agenda/sustainable-agriculture/en/

such as conservation technologies that enhance input use efficiency and reduce pollution, introduction of strategies that include resilience and ability to withstand environmental risk, adoption of recycling technologies, and transition from non-renewable to renewable technologies (Zilberman, 2014).

CSA shares many objectives and guiding principles with green economy and sustainable development approaches, including a prioritization of food security and a desire to preserve natural resources (Jayne et al., 2018). CSA is also closely linked to the concept of sustainable intensification (FAO, 2013; Campbell et al., 2014). In many cases, Jayne et al. (2018) argues that sustainable intensification constitutes a subset of practices that are potentially climate smart under certain current and future climatic conditions. However, CSA extends the sustainable intensification concepts through a more progressive dimension, more concern about future potential changes and the need to be prepared for them (FAO, 2013). Thus, CSA is not a set of new agricultural practices or a new agricultural system (FAO, 2013). Instead, it is understood as a new approach to guide necessary changes to agricultural systems in order to jointly address challenges of food security and climate change (Branca et al., 2011; Grainger-Jones, 2011; FAO, 2013; Lipper et al., 2014).

4 Defining Climate Smart Agriculture

As discussed in part I of the paper, the concept of CSA has various dimensions are there is no clear definition for which agricultural technology or management practice is climate smart. In fact Lipper and Zilberman (2018), argue that not every practice in every field would have to contribute to food security, adaptation and mitigation, but meeting the three objectives of CSA should be considered at broader spatial and temporal scales. The difficulty in CSA definition stems in part from the fact that not a single technology or management practice option has the ability to achieve or address all the three pillars of climate smart agriculture. This is because technology options or management practices vary widely in their potential impacts on agricultural productivity, climate change resilience, and GHG mitigation. Most technology options or management practices employed by farmers generally improve productivity, whiles their impacts on resilience and mitigation are particularly variable. In most cases therefore, a combination of technology options or management practices may be required, together with the enabling or supporting factors outline earlier to make agriculture truly climate smart. One of the key concept that therefore comes up when talking about CSA is trade-offs and synergies. Climate smart agriculture technologies and management practices are therefore supposed to amplify these synergies and accommodate trade-offs. These synergies and trade-offs should be between food security, adaptation, and the mitigation objectives of CSA. There is however a general consensus that CSA has the potential to capture and drive huge synergies between mitigation and sustainable agricultural development (Lipper and Zilberman, 2018).

Climate smart agriculture also has a context specificity dimension with variability across space and time. These differences are in part due to the space-time variability of climate variables which causes variations in biophysical variables but also differences in institutional, distributional and socio-economic factors (Branca et al., 2018). CSA is therefore not a silver bullet and hence the need to prioritize and develop tailored approaches for each specific region and context. Space and time variability also means that CSA needs to be an evolving process, changing constantly to respond to climatic changes. Zilberman et al. (2018) also emphasized that climatic impacts related to heterogeneity and uncertainty means that different regions are affected differentially by climate change. The heterogeneity in impacts, as well as gains and losses from engagement in mitigation activities (herein CSA technologies and management practices), may contribute to the diverse responses (*ibid*).

Furthermore, the timing, magnitudes and locations of different impacts of climate change are not known with certainty. Another important aspect is that in the context of agricultural production and technology adoption is that risk reduction is often much more important for smallholder producers than productivity increases or mitigation per se (Kraaijvanger and Veldkamp, 2015). In light of the limited capacity of smallholders to bear risk, Barrett et al. (2001) observed that they tend to select farm portfolios that stabilise income flows and consumption. Smallholders are therefore more focused on stabilizing income and consumption smoothening which reflects more of pillar one and two of CSA and less on pillar three. Thornton et al. (2018) on evaluating different candidate technology options for CSA also observed that many of these have positive impacts on at least one or two of the three CSA pillars, and some on all three. The evidence base was however mixed and they suggested that broad-brush targeting of CSA interventions was not going to be appropriate, from a technical stand-point, given that impacts were not clear and/or highly context-specific.

Therefore identifying which agricultural technologies is climate smart involves consultative processes, prioritization and scale-up potentials because of differential impacts or outcomes. Lipper and Zilberman (2018) gives an example of an EC funded FAO CSA project, where consultations with national policy makers and stakeholders including representatives from farmers associations and other civil society groups identified a set of possible CSA options. The aforementioned authors also makes mention of the World Bank/CCAFS profiles which analyses a range of technologies and practices that are currently being practiced in selected countries or likely to be beneficial under projected climate change conditions, including from traditional as well as science based sources. In the World Bank/CCAFS country specific profiles[9] a set of criteria for identifying (stock-taking) climate smartness of the technologies which also give information on the economic, environmental and social impacts of the technologies has been provided for 20 countries across South America, Sub-Saharan Africa, South Asia and Europe.

The knowledge product as suggested by Lipper and Zilberman (2018), also serve as a methodology for assessing a baseline on climate smart agriculture at the country level that can guide climate smart development. Cacho et al. (2018) also argue that the appropriate application of CSA principles depends on specific conditions that vary between and within countries. They however suggested that knowledge obtained from datasets, which combine household, geographical, and climate data will be vital in designing CSA policies that enhance food security and climate resilience while also taking advantage of mitigation opportunities to obtain financing. Adaptive learning will be vital in CSA because climate change and technological progress, new opportunities, and information accumulated are ongoing and evolving processes. Secondly, adopting agriculture to climate change requires the need for a portfolio of CSA strategies, which will be significantly more effective than CSA strategies working in isolation.

Based on the empirical literature and the developed conceptual framework, I propose a new way to define climate smart agriculture. Climate Smart Agriculture (CSA) is hereby defined as the interaction of tools and techniques, and enabling or supporting factors to achieve agricultural productivity, climate change resilience, and GHG mitigation while recognizing the need for trade-offs and synergies. Another important consideration for the concept of CSA is that it requires direct tools or techniques to transform agriculture into a state of "climate smartness", herein to achieve the three pillars of CSA. These tools or techniques I herein call climate smart agriculture technologies and management practices. Hence, I also propose a definition for Climate Smart Agriculture Technologies or Management Practices (CSA-TMP). Climate smart agriculture technologies or management practices are hereby defined as a set of tools and techniques geared towards achieving agricultural productivity, climate change resilience, and GHG mitigation. A technology or management practice is specifically considered a climate smart agriculture technology or management practice if it addresses pillar three of climate smart agriculture and a second pillar (either pillar one or pillar two or both). However, pillar three is a necessary condition to be CSA.

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[9] http://sdwebx.worldbank.org/climateportal/index.cfm?page=climate_agriculture_profiles, accessed on 24.07.2018

Hence achieving "climate smartness" of agriculture at the farming system[10] level entails a farmer employing either one or a complementary set of climate smart agriculture technologies or management practices which have a net neutral or positive mitigation effect in addition to either increasing agricultural productivity, or climate change resilience or both. In cases where a complementary set of climate smart agriculture technologies or management practices is employed by a farmer, the net effect on pillar three, must be either zero (neutral) or positive.

For agriculture to be truly climate smart, it should be also worth noting that these tools and techniques (herein CSA-TMP) are not sufficient alone to achieve climate smartness. They require some enabling or supporting factors such as Climate Smart Polices (CSP), Climate Smart Institutions (CSI) and Climate Smart Financing Mechanisms (CSFM). These set of tools and techniques in some cases may need to be complemented directly by services in the form of weather information and advisory services via extension (e.g. technical know-how), credit, insurance and other support measures. The proposed definition of climate smart agriculture technologies or management practices is however without its own shortcoming and this therefore paves the way for further research in terms of empirical measurement of climate smart agriculture. At present, no formal empirical measurements exist for the concept of CSA, and this is understandable because of the complexity of the concept and its various dimensions. At the same time an overarching definition of climate smart agriculture technologies and management practices is particularly challenging because productivity increases, resilience and GHG emission reduction by different CSA-TMP varies across space, time and location. Furthermore, what is CSA varies from one geographic location to the next due to differences in biophysical, institutional, distributional and socio-economic factors.

In addition to the competing objectives of increasing food security through increases in productivity and incomes, building resilience and adapting to climate change and reducing greenhouse gas emissions, seems not to be the key focus in the agricultural development debate. For example, the FAO (2013) considers climate change mitigation as a "potential secondary co-benefit", especially in the case of low-income, agricultural-based populations. However, increasing food security through increases in productivity and incomes should be done through the lens of synergies and trade-offs, to achieve the other two pillars of climate smart agriculture. Some early research have been focused on the economic impacts of the adoption of climate smart agriculture technologies and management practices. However, there is the need for multi-dimensional assessments that consider agricultural system

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[10] By farming system here, I am referring to the definition by Fresco and Westphal (1988) which is "decision making units comprising farm household, cropping and livestock systems that transform land, capital and labour into products for consumption and sale". It is a mix of farm enterprises such as crop, livestock, aquaculture, agro forestry and fruit crops (Sharma et al., 1991) to which farm families allocate its resources in order to efficiently utilize the existing enterprises for increasing the productivity and profitability of the farm

performance in economic, environmental and social dimensions and the inevitable trade-offs among those dimensions (Antle, 2011; Antle et al., 2014). Furthermore as reported by Tschakert (2007), there is still limited information currently that quantifies what the trade-offs and synergies are in different contexts and for different CSA-TMP. Thornton et al. (2018), also suggest that the technical potential of CSA interventions in developing country agriculture is going to remain difficult to estimate because of heterogeneity in outcomes. However, CIAT (2015) suggests that a combination of field to farm level models can help predict potential impacts of technologies on multiple dimensions of farm performance across the three pillars of climate smart agriculture.

Furthermore, setting pillar three of CSA as a necessary condition for "climate smartness", means that there should be means to define pillar three either qualitatively or quantitatively. Notwithstanding, irrespective of how pillar three is defined qualitatively or quantitatively, pillar three can also be observed both directly and indirectly, however one may ask, which is the best way to define it? A direct observation of pillar three in quantitative terms could be for example the net tonnes of CO_2 equivalent sequestered per cropping season or per annum by a particular CSA-TMP. An indirect or anecdotal observation of pillar three on the other hand could be for instance improved soil nutrient supply and hence the forgone need (savings accrued) for external nutrients inputs or the promotion of carbon sequestration through an increase in the carbon content of the soils and aboveground biomass by a CSA-TMP. Additionally, an indirect or anecdotal observation of pillar three could be in terms of neutral mitigation[11]. In this regards, a CSA-TMP that nether contributes to GHG emission nor reduce GHG emission meets the necessary condition of being a climate smart agriculture technology or management practice. What is however clear in using the appropriate scale for defining pillar three of climate smart agriculture is that qualitative assessments will not do justice of determining truly GHG mitigating climate smart agriculture technologies or management practices. Providing direct quantitative measurement across anecdotal observations might be the way to truly measure "climate smartness" under the proposed definition. Furthermore, since the three pillars of climate smart agriculture contains already key existing and measurable concepts such as productivity (pillar I), resilience, vulnerability (pillar II) and carbon sequestration (pillar III), this can be used as proxies that can provide a basis for future empirical measurements of climate smart agriculture. With this approach, several climate smart agriculture technologies and management practices can be easily compare across the three pillars of CSA. With better empirical measurements, useful information on potential impacts of these climate smart agriculture technologies and management practices will lead stakeholders such as, farmers, NGOs and policy makers to take more evidence-based decisions.

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[11] In the climate policy discourse, this refers to the so called "Carbon neutrality", which is having a net zero carbon footprint

Hence, despite proposing these new ways of defining or viewing climate smart agriculture, further empirical work is need in the area of measurement. At the farm or micro level, studies on the measurement of climate smart agriculture along the pillars of agricultural productivity, climate change resilience, and GHG mitigation will be needed across different biophysical and social contexts. Another interesting way to view future empirical measurements of climate smart agriculture at the macro level, can be observed from the conceptual framework developed earlier in part two of the paper. A modelling framework that considers the various climate smart agriculture technologies and management practices, and the enabling or supporting factors (climate smart polices (CSP), climate smart institutions (CSI) and climate smart financing mechanisms (CSFM)) that was pointed out earlier, can be used to better observe trade-offs and synergies of climate smart agriculture. This might serve as an important signal for the prioritization and scaling up of promising climate smart agriculture technologies and management practices.

5 Conclusion and future outlook

The definitions of the concept of CSA is varied, however a common understanding of the various definitions is the need to reorient agriculture to deal with climate change where providing benefits like increases in agricultural productivity and incomes, resilience and mitigation. For agricultural to be climate smart, there is the need to apply relevant tools and techniques, herein called CSA technology and management practice at the micro-level and the provision of enabling or supporting factors such as policies, institutions and financing mechanisms from the macro-level. Truly achieving CSA however, might call for a landscape approach, which involves the management of production systems and natural resources covering areas large enough to produce vital ecosystem services but small enough to ensure that actions can be easily carried out by land users to produce those services (FAO, 2013).

The approach to identifying climate smart agriculture technology and management practice is context specific with both space and time variations. Identifying relevant CSA technologies and management practices that have the high economic, social, and environmental gains requires a bottom-up prioritization and consultative framework with experts, relevant stakeholders and farmers. This is essential because there is a complex matrix of individual farms, biophysical, and socio-economic dynamics, institutional and market capacity, varying local needs and interests, across a range of stakeholders (e.g. farmers, local agricultural experts, researchers, donors and policy makers). Including all of them in the prioritization framework leads to a better inclusion, acceptance and a higher likelihood of adoption CSA technologies and management practices.

In this regards there is no universal definition of what a CSA technologies and management practices is because of the context-specificities. However, our proposed definition leads the way to a more concise and clear definition of agricultural systems that are "climate smart". There is the need to also developed empirical measurement scales for CSA. Empirical measurement of CSA can help complement the prioritization of CSA approaches by providing quantity information and measurements on the three pillars of CSA. At the same time, key concepts such as productivity, resilience, vulnerability and carbon sequestration embedded in CSA provide some form of basis for future empirical measurements and comparisons of climate smart agriculture technologies and management practices across space and time. These concepts can be used to construct appropriate indices that allows for the comparison of several technologies across different geographical and socio-economic contexts. At the macro level, ex *ante* economic models can also play a vital role in the CSA prioritization and scale-up process by helping to identify the most feasible, and trade-off and synergy optimizing CSA technologies and management practices. At the same time ex *post* economic models will be vital to making adjustments in agricultural production systems because of uncertainties related to climate change.

A key and often missed aspect of CSA is consumption and utilization. Food waste and post-harvest losses are key components in ensuring that agriculture is climate smart. Gustavsson et al. (2011) suggests that global food losses and waste amount to a third of all food produced. The aforementioned authors estimated that consumer food waste is about 95-115 kg of food per person per year in developed countries. In the case of SSA postharvest losses due to poor harvesting techniques, storage facilities, and pests and diseases cause losses of about 37% (Gustavsson et al., 2011). These losses and waste also means that the GHG emitted during their production have served no useful purpose. This is especially true when the food has reached the end of the food chain, when the embedded emissions for transport and conservation are very high (FAO, 2013). Combating food waste and losses are key to ensuring the sustainability of agricultural systems and climate smartness. In this regards, life cycle analysis (LCA) in food value chains will be important in assessing climate smartness and identifying area in the food production systems that require interventions and changes.

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