RESEARCH PROGRAM ON
Climate Change,
Agriculture and
Food Security

Report: CCAFS impact assessment of national policy engagement in Kenya on uptake of climate-smart agriculture technologies and practices

December 2020

Boscow Okumu

CCAFS impact assessment of national policy engagement in Kenya on uptake of climate-smart agriculture technologies and practices

Report

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

Boscow Okumu

To cite this report

Okumu B. 2020. CCAFS impact assessment of national policy engagement in Kenya on uptake of climate-smart agriculture technologies and practices. CCAFS Report. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

About CCAFS reports

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

About CCAFS

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is led by the International Center for Tropical Agriculture (CIAT), part of the Alliance of Bioversity International and CIAT, and carried out with support from the CGIAR Trust Fund and through bilateral funding agreements. For more information, please visit https://ccafs.cgiar.org/donors.

Contact us

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

Abstract

This study assessed the impact of engagements by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) at policy and household levels in Kenya. Specifically, the study assessed the extent to which CCAFS engagement contributed to the observed changes in terms of shaping policy and climate-smart agriculture (CSA) coordination among others. At the household level, the study assessed the factors influencing uptake of CSA practices among smallholder farmers and the subsequent impact of the CSA practices on agricultural yield, livestock holding and welfare of households. The study used a mix of qualitative and quantitative approaches. Specifically, key informant interviews, focus group discussions, observation and cross-sectional data from household interviews and a range of econometrics techniques were used to assess the impact at household level, namely, propensity score matching and instrumental variable approach.

The study revealed that CCAFS interventions have led to development of a range of policies aimed at promoting CSA. In effect, several counties have developed county policies on climate change, some have established climate change units and climate change funds all aimed at promoting CSA. However, apart from the multi-stakeholder platforms, the coordination of CSA practices from the national government to the county government has been weak. At the household level, the choice of CSA practices among smallholder farmers was found to be influenced mainly by age, sex, marital status and education of household head. The choice of CSA practices is also influenced by smartphone ownership, residential status (i.e., whether native or immigrant), training on CSA, provision of input subsidy by counties, past experience of hailstorms/insufficient rains, visit by agricultural extension officers, knowledge on CSA and whether a household is a crop farmer. Other factors that were found to influence the choice of CSA practices were household monthly income, household access to loans and distance to the nearest crop market. The choices of the type of CSA practices were also mainly dominated by males.

The two empirical approaches employed in the study revealed that uptake of CSA by smallholder households had a statistically and economically significant impact on household welfare as measured by per capita household expenditure, total value of livestock holding

and total value of agricultural yield. A number of policy recommendations are also highlighted.

Keywords

Agriculture; climate change; food security; climate-smart agriculture; impact assessment.

About the author

Boscow Okumu is an experienced economist with a demonstrated history of working in the Kenyan government (at national and devolved levels). He has over ten years of experience in monitoring and evaluation of government policies, development of indicators, M&E frameworks at preparation of progress reports at national and devolved levels of government.

Contents

Chapter one

Introduction and background

Arid and semi-arid lands comprise about 13.6 million square kilometres of sub-Saharan Africa (SSA) and support about 290 million people (Notenbaert et al. 2013). Due to depletion of water resources, it is estimated that one in every four people might suffer from extreme water scarcity by 2025 (Nikolaou et al. 2020). Subsequently, the proportion of arid and semi-arid lands in Africa is expected to increase by between 5% and 8% by 2080 (Collier et al. 2008). These areas are also the most affected by climate change and variability due to high dependence on rainfed agriculture. The most vulnerable sectors to the effect of climate change are crops, livestock and fisheries (Sere and Steinfeld 1996). These sectors account for about 60% of Africa's labour force therefore at the greatest risk (Collier et al. 2008). The SSA region also coincides with areas of low food security and high prevalence of poverty (Collins-Sowah 2018). Smallholder farmers have been the greatest casualties of climate change since they have low resilience to climate shocks due to inadequate resources, safety nets, inadequate access to financial services, and lack of alternative sources of livelihoods (Campbell et al. 2014; Collins-Sowah 2018). Reducing the vulnerability of smallholder farmers to the effects of climate change variability and strengthening their adaptive capacities have therefore been the priority of most developing countries in an effort to ensure food security and improving livelihoods of locals (Lipper and Zilberman 2018).

Within the East African region, challenges facing agricultural systems include: degradation of land, soil water and other ecosystems; economic barriers such as lack of access to inputs, markets, capital, credit and finance; poor infrastructure, rising land prices and land fragmentation. These factors have significantly limited productivity of the agriculture sector. Moreover, approximately 95% of the food in the East African region is produced under rainfed agriculture (Njeru et al. 2016). In Kenya for instance, the erratic rainfall patterns, continuous rise in temperature experienced with episodes of droughts and floods is a clear evidence of climate change (GOK 2010). Kenya being predominantly reliant on rainfed subsistence agriculture, it is more vulnerable to the effects of climate change variabilities particularly changes in temperature, precipitation patterns, and extreme weather events. Most smallholder farmers in Kenya also depend on agriculture for their livelihoods (Ochieng

et al. 2017). Therefore, to cushion them from the effects of climate change, building their adaptive capacity and resilience is critical. However, this is highly dependent on their ability to cope with the impacts of weather shocks, disasters and capacity to absorb the impact of and recover from the shock (Wineman et al 2017; Wekesa et al. 2018).

It is against this backdrop that the Food and Agriculture Organization (FAO) launched the concept of Climate Smart Agriculture (CSA)[1] to guide the management of agriculture, achieving food security and combating the effects of climate change (FAO 2010; FAO 2013; Verhagen et al. 2014; Arslan et al. 2014; Kabubo-Mariara and Kabara 2015; Lipper and Zilberman 2018). The CSA concept seeks to: sustainable increase food security through increases in productivity and incomes; build resilience and adapt to climate change; and reduce greenhouse gas emissions (mitigation) (Collins-Sowah 2018; Lipper et al. 2014). Therefore, in order to transform agricultural systems and make them more productive and resilient while minimizing GHG emissions under the changing climate, CSA presents the best opportunity for transforming and uniting agriculture, development and climate under a common agenda through economic, environmental and social integration (Collins-Sowah 2018). In this study, we consider CSA practices as farming practices that farmers adopt to enable them to adapt to the negative effects of climate change and variability in order to improve farm productivity and profitability.

The study context: Background of CCAFS interventions in Kenya

The agriculture sector in Kenya contributes about a third of the GDP and about 60% of export earnings (KNBS 2020). It is therefore highly likely to be most affected with climate change and variability since the sector is more reliant on rainfed agriculture. To address the increasing challenge of global warming and declining food security, CCAFS has been working with the Kenyan government since 2011 in providing technical input into policies and frameworks on climate change in relation to agriculture practices. Through the engagement, CCAFS working with other CGIAR centres contributed to the development of the National

[1] Climate Smart Agriculture is an approach that guides actions needed to transform and reorient agriculture systems to effectively support development and ensure food security in a changing climate. It aims to sustainably increase agricultural production and incomes, build resilience of agricultural systems to climate change and minimize GHG emissions (Lipper et al. 2014; CCAFS and Verhagen et al. (2014) also defines CSA as integrated approach to achieve food security in the face of climate change, while also mitigating climate change and contribute to other development goals

Climate Change Response Strategy (NCCRS), the National Climate Change Action Plan (NCCAP) and the Climate Change Policy, and the Kenya Climate Smart Agriculture Strategy (KCSAS) and the related Implementation Framework (KCSAIF). CCAFS has also guided local and international development organizations on focusing their agriculture work under the CSA approach as well as influencing the investments and activities of various stakeholders such as the World Bank, SIDA, UNDP, EU, GIZ, FAO, AGRISS, World Vision, IFAD, and USAID among others, and NGOS such as Islamic Relief, Catholic Relief Services, CARITAS, One Acre Fund and the Red Cross.

CCAFS, along with Biovision and the Climate Change Unit within the Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MOALFC), has also been helping launch the CSA multi-stakeholder platform (MSP) that brings together organizations to share information and coordinate activities on CSA, which will help them to effectively and accurately report on CSA progress to various national and global processes. As a result, many organizations are now using CSA approaches when working with farmers in Kenya. A World Bank assessment of the county risk profiles revealed that Kenyan smallholder farmers lack inputs, irrigation and markets. The farmers are also more vulnerable to climate change and variability since they are more reliant on rainfed subsistence agriculture. The situation across counties is also very heterogeneous, calling for county-specific interventions. The Kenyan government therefore established the Kenya Climate Smart Agriculture Project funded by the World Bank. The project aims at increasing agricultural productivity, building resilience to climate risk among small scale farmers and providing an effective response in the event of a crisis or emergency.[2]

In addition, at the county level, a CCAFS-funded project led by the Alliance of Bioversity International and CIAT is developing county risk profiles that may also be informing county development plans or other work at the county level. Subsequently, some counties have been able to: establish Climate Change Units (e.g. Tharaka Nithi, Homa Bay and Kakamega among others); develop policies and Bills/Acts (e.g. Tharaka Nithi) to address climate change issues; establish climate funds (such as Isiolo and Tharaka Nithi); mainstream climate change

[2] https://ccafs.cgiar.org/research/results/county-level-climate-risk-profiles-guide-usd-250-million-investment-kenya#.Xwbo0NycHIV

into County Integrated Development Plans (CIDPs) and spatial plans and implement green initiatives such as solar street lighting, energy efficient cook stoves and climate smart agriculture.

CCAFS, ICRAF, ILRI and CIAT have also been instrumental in the development of Kenya's climate smart agriculture Framework Program (CSA-FP). The program aimed at guiding investment into climate resilient and low carbon agriculture. By mid-2015 the CSA-FP was integrated into Kenya's Intended National Determined Contribution (INDC) submission to the UNFCCC. The aim of the INDC is to reduce the country's greenhouse gas emissions by 30% by 2030 relative to a business-as-usual scenario of 132 Mt CO2eq.[3] This was the outcome of a CCAFS-led process on "Taking Forward Kenya's NCCAP 2013-2017". The meeting also created a momentum for implementation of the Agriculture priority actions in the NCCAP (2018-2022).[4]

CCAFS has also been working with the Government of Kenya through the Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MOALFC) to discuss and take forward priority actions for the agriculture sector identified in the NCCAP (2018-2022). In the dairy sector, Kenya is leveraging on climate finance to promote sustainable development. A meta-analysis of Nationally Appropriate Mitigation Actions (NAMAs) was conducted to identify best practices. Subsequently, climate smart feeding and husbandry practices were then disseminated to 600,000 farmers with 25% being women farmers from a variety of dairy organizations.[5] It was envisioned that the climate smart actions in the dairy sector could be scaled up to reach 1.8 million households, decreasing the country's emissions by 3.3% of its 2010 emissions while sustaining 180,000 jobs in the sector and improving smallholder incomes by USD 1000-2000 per year.[6]

[3] https://ccafs.cgiar.org/research/results/kenya-integrates-climate-smart-agriculture-its-intended-nationally-determined#.XwcAu9ycHIV

[4] https://cgspace.cgiar.org/bitstream/handle/10568/67906/07outcomecase.pdf?sequence=6

[5] https://ccafs.cgiar.org/outcomes/scaling-climate-smart-dairy-practices-kenya-through-nationally-appropriate-mitigation

[6] https://ccafs.cgiar.org/research/results/scaling-climate-smart-dairy-practices-kenya-through-nationally-appropriate#.XwcIntycHIV

In partnership with the East Africa Dairy Development (EADD) program and ILRI and ICRAF, Heifer International has been working with 200,000 farmers to improve dairy production and provide access to markets. The main aim of the EADD launched in 2008 in Kenya was to assist 179,000 smallholder farmers owning less than five acres of land to participate profitably in the dairy industry. Its major focus was on improving food and nutrition security, increasing farmers' incomes and facilitating access to markets (Nyasimi et al. 2014). The EADD also adopted climate smart agriculture as an objective based engagement with CCAFS scientists, and mounting evidence that better feeding using fodder banks, improved pasture species, planted legumes and crop by-products and manure management can contribute to reductions in GHG emissions and improved income for farmers[7]. Heifer International also partnered with the CCAFS-funded Standard Assessment of Mitigation Potential and Livelihoods in Smallholder Systems (SAMPLES) project EADD and adopted CSA interventions in the new phase of the program. CCAFS scientists have also been engaging with FAO of the UN at an EADD site in Kenya (Bomet, Nandi and Elgeyo Marakwet counties) to estimate GHG emissions and productivity of dairy systems[8].

Another project was the Drought Tolerant Maize for Africa (DTMA) project launched in 2006 coordinated by CIMMYT and the International Institute of Tropical Agriculture (IITA). Its main objective was to develop and disseminate drought tolerant, high yielding, and locally adapted varieties of maize. In collaboration with national agencies, NGO, seed companies, certification agencies and farmer groups in 13 countries, 34 new drought tolerant maize varieties were developed and distributed to 2 million farmers whose yields have increased by 10-34%. The cumulative economic benefits to farmers and consumers amounted to $900 million. The Water Efficient Maize for Africa (WEMA) project launched in 2008 also aimed at improving food security and livelihoods among smallholder farmers by developing maize hybrids that tolerate drought and resist insect pressures. It was coordinated by the African Agricultural Technology Foundation (AATF), CIMMYT and Monsanto in Mozambique, Kenya, South Africa, Tanzania and Uganda. The project has released nine maize hybrids that are

[7] https://ccafs.cgiar.org/research/results/east-africa-dairy-development-program-adopts-climate-smart agriculture#.XwcIodycHIV

[8] https://ccafs.cgiar.org/research/results/east-africa-dairy-development-program-adopts-climate-smart-agriculture#.XwcIodycHIV

tolerant to drought, early maturing and disease resistant. The hybrid maize yields 20-35% more grains under drought conditions than existing commercial hybrids.

Further, the Africa Risk Insurance Mechanisms was set up under the Africa Union to enable insured countries to plan their response to drought and prevent them from a full humanitarian crisis. The scheme issued policies to governments of Kenya, Mauritania, Mozambique, Niger and Senegal, providing $135 million in drought insurance coverage. Kenya is also among the countries that have experimented with national weather index-based insurance schemes in the crop and livestock sectors. Kenya also has the index-based livestock insurance (IBLI). The Agro-dealer Development Programme also provides training, capital and credit to small and medium sized agro-dealers in several African countries. Agro dealers are trained to provide agro-advisory information on the best inputs such as fertilizers and certified quality seeds that are resistant to pests and diseases. In Kenya, the programme increased farmers' access to inputs by reducing the distance they have to travel to reach an agro-dealer from 40 km to 7 km in project areas. As a result, fertilizer use increased by 30% amongst women whose needs are met by the agro-dealers.

The Programme for African Seed System (PASS) also sought to dramatically increase Africa's capacity to breed, produce and disseminate quality seed of staple food crops such as maize, rice, cassava, beans, sorghum and millet that are highly adaptable to diverse climate regime. The project aimed to develop seed systems to deliver certified crop varieties that are drought tolerant, and disease and pest resistant to smallholder farmers efficiently, equitably and sustainably in 13 sub-Saharan African Countries. In effect, certified seed production by private companies has increased since 2007.

Programs such as the Kenyan TV show "Shamba Shape Up" have also been instrumental in Kenya by supporting smallholder farmers to make over their farms by providing help with recurrent agricultural challenges such as pests and diseases, lack of water and crop production among others. The show has dedicated to CSA up to 35% of total programme time. The number of viewers per month is over 9 million, 42% of which have adopted new

practices9. Some of the successful case studies in Kenya that have been identified by Nyasimi et al. (2014) are: East Africa Dairy Development Project that adopt a value chain approach in tackling risk management and climate variability; drought tolerant maize and water efficient maize to increase crop resilience to drought and increase productivity; and Africa Risk Insurance Mechanism, the Agro-dealer Development programme, Programme for Africa Seed Systems (PASS) that adopts risk management practices that generate and disseminate agro-advisory services-weather information, insurance, micro-finance, credit and access to markets.

Rationale of the assessment and research questions

Kenya is currently implementing its third Medium Term Plan of Kenya Vision 2030 and counties are in their second CIDPs. These plans have been aligned to international obligations and development agendas that Kenya is party to such as: the United Nations Agenda 2030 for Sustainable Development Goals, AU agenda 2063, and the United Nations Convention on Climate Change (UNFCCC), among others. The plans seek to address the effects of climate change on agricultural systems through development and implementation of strategies for adaptation and mitigation including early warning, early preparedness, response and improved climate smart agriculture technologies and practices and better land management. At the local level, Kenya's Vision 2030 seeks to have a climate-resilient and low carbon sustainable agriculture that ensures food security and contributes to national development goals through: addressing vulnerability due to changes in rainfall and temperature, extreme weather events, and unsustainable land and water management and use; reducing GHG emissions from agriculture; establishing enabling policy, legal and institutional frameworks for effective implementation of climate-resilient and low-carbon sustainable agriculture; and minimizing effects of underlying cross-cutting issues such as low human resource capacity and lack of finance (Solomon et al. 2018; GoK 2018).

However, although CCAFS has had over ten years' engagement with the Kenyan government at both national and county level, the impact of this initiative at policy and household level has not been determined. This is despite the significance of the concept in ensuring food and

[9] https://ccafs.cgiar.org/research/results/tv-show-helps-mobilize-east-african-farmers-adopt-climate-smart-agriculture#.XwcFAdycHIV

nutrition security in Kenya, one of the pillars of the “Big Four” Agenda to achieve Vision 2030. Further, despite the multiple benefits of CSA and the interventions by state and non-state actors under various initiatives, there is still a dearth of evidence on the impact of the interventions on shaping policy and coordination efforts. There is also lack of evidence on farmers’ incentives and conditioning factors that influence the uptake of CSA practices as well as the impact of the interventions on the pillars of CSA at household level. It is therefore not known if these interventions have improved household welfare, food security or resilience of households. There is also dearth of evidence on the extent to which CSA policies and practices have addressed issues of gender and youth.

Most of the studies in Kenya have been selected descriptive case studies with different approaches making comparison difficult (see Nyasimi et al. 2014; Chesterman and Neely 2015; Radeny et al. 2018; Wekesa et al. 2018). The outcome measures have also been varied and subjective. The existing evidence are also hampered by selection bias. In addition, most quantification of impact is based on country studies or local administrative units while traditionally managing climate risk has been the responsibility of households.

The current two-tier system of governance in Kenya also makes the promotion of CSA practices feasible since extension services/agricultural services have been devolved different from the prior system of governance. In addition, to the best of our knowledge, there has not been any assessment conducted at national and devolved level on the effect of the CCAFS interventions.

The assessment, therefore, seeks to fill these gaps by addressing the following questions: What changes can be observed in relation to the objectives of CCAFS’s activities in Kenya especially on CSA policy and implementation? To what extent has CCAFS engagement contributed to the observed changes in terms of shaping policy and CSA coordination efforts? What might have happened without the engagement of CCAFS and its CGIAR partners? What factors influence the uptake of CSA practices/technologies? What factors influence the choice of CSA practices among smallholder farmers? What is the effect of the CSA practices on household food security, income, yield, resilience and vulnerability? Are there unintended impacts? What mechanisms delivered the impact, and what lessons can we learn from this process? What are key contextual features for these mechanisms?

Chapter two

Related literature and CCAFS impact pathways

This section presents a review of related literature on CSA at policy level and at household level as well as CCAFS envisioned impact pathways. The review looks at both theoretical and empirical literature.

Policy level interventions and related literature

A number of studies have tried to explore the contribution of climate smart policies at different levels. According to McCarthy et al. (2018) climate smart policies encourage improved decision making, enhance resilience and adaptive capacity to changing agro-climate conditions and adoption of best feasible technologies, improve input use, and post-harvest practices at farm level. Some of the climate smart policy scopes that can amplify CSA adoption include: cash transfer programmes, subsidized index-based insurance (livestock and crops), and input subsidy programmes. However, although these policies were meant to reduce poverty and increase food security and therefore aimed at reducing economic vulnerability rather than climate vulnerability, they have proved effective in managing climate risk and potentially mitigating effects of climate change (see Caron et al. 2018; Collins-Sowah 2018).

According to Lipper and Zilberman (2018), improvement of climate change and agricultural governance through better coordination and institutional strengthening is key for success of CSA. This is based on the premise that the institutional environment can incentivize farmers and increase their ability to invest in agricultural practices and adapt to climate change (McCarthy et al. 2018). McCarthy et al. (2018) also posit that institutional innovations at macro and farm level such as “climate smart” extension programs, full spatial coordination among farmers to deal with associated externalities and social safety nets etc. can support CSA technology adoption. Caron et al. (2018) identified a number of areas of institutional support that are critical for uptake of CSA technologies and management practices. These include: provision of attractive and viable financial and risk management tools; increasing

information dissemination needed for smallholders to increase knowledge and technical skills; enabling farmer groups and cooperatives to access high value markets; and protecting livelihoods of smallholder farmers who are protected through safety nets in the event of adverse weather events. Collins-Sowah (2018) also highlighted the importance of private and public sector partnerships in expansion and improvement of the supply chain of credit and farm level inputs and outputs.

The promotion of CSA is also heavily reliant on collaboration with research institutions to ensure farmers get access to the right technologies and information as well as the know-how in the use of the technologies. In addition, a conducive environment, macroeconomic stability, assurance of peace and security functional markets and incentives can also stimulate CSA adoption (see Westermann et al. 2015; Collins-Sowah 2018). Access to information has also been shown to be a critical factor in adoption of CSA technologies. Provision of weather forecast information can serve as an early detector of growing conditions and can help farmers adjust to planting seasons by adjusting planting dates hence improving agricultural productivity, managing risks and taking advantage of favourable weather conditions (Hansen et al. 2011; Thornton et al. 2018). Moreover, integrating agricultural advisory services and input markets with tailored climate services which provide new information to complement and extend farmers' knowledge can empower smallholder farmers and reduce climate uncertainty (CIAT 2015). Lipper et al. (2014) also posits that CSA promotes coordinated actions by farmers, researchers, private sector, civil society and policymakers towards climate-resilient pathways through: building evidence, increasing local institutional effectiveness, fostering coherence between climate and agricultural policies and linking climate and agricultural financing.

Nyasimi et al. (2014) also highlight that multi-stakeholder collaboration is key to sharing information and addressing similar agricultural problems at different levels (national and regional), and that governments must support and enable growing private sector by providing appropriate markets, infrastructure and policies. They also state that an enabling institutional and policy environment is needed that supports agricultural research and education oriented to farmers' needs as well as the diversification of farming systems; climate change adaptation strategies must be appropriate to women's capacities and needs; responsive national and regional markets should be promoted to provide access to credit

and finance schemes to enable farmers to invest in new and emerging climate smart technologies; and that CSA practices need to provide incentives and market opportunities that will transform subsistence agriculture into profit-led enterprises and that the practices should support the development of enterprises that offer diverse and sustainable source of income to help cushion families through difficult periods such as droughts and floods.

Household level interventions and related literature

At the household level, a number of studies have tried to tease out the drivers of adoption of CSA practices as well as their impact using different approaches. For instance, Wekesa et al. (2018) sought to determine the drivers of adoption of CSA practices and the effect of adoption of CSA on household food security among smallholder farmers in Teso North Sub-county, Busia county of Kenya. Using the Principal Component Analysis and the multinomial endogenous switching regression model, they found that adoption of CSA packages was mainly influenced by gender, farm size and value of productive assets. They also found that the impact of CSA was greater for households that adopted various categories of CSA practices.

Another study by McCord et al. (2015), investigated factors contributing to varying levels of crop diversification and implications for crop production across an upland-lowland gradient on Mt Kenya’s north-western slopes, a semi-arid irrigated agricultural system. Using regression analysis on household level survey data, they found that household income, field size, exposure to extension services, and suitability of environmental conditions are related to likelihood of smallholder crop diversification. Crop diversification is also a strategy that households may employ to reduce vulnerability to external stress factors, such as climate change (Baumgartner and Quaas 2010; Lin 2011). A number of studies have also shown that adoption of CSA technologies like crop diversification are determined by land suitability, income level, risk avoidance, contact with extension officers and social norms (Cutforth et al. 2001; Di Falco and Perrings 2003).

According to Nyasimi et al. (2014), to build smallholder farmers resilience to climate change, there is need for a greater adoption of integrated CSA technologies. While analysing the uptake and impact of CSA technologies on food and nutrition security, incomes and asset accumulation in climate smart villages (CSVs) in Kenya, Radeny et al. (2018) found that there

was an increase in uptake of CSA technologies and innovations across the CSVs coupled with improved agronomic and livestock management practices. In addition, they found that adoption of crop and livestock related CSA technologies and practices have positive and significant impact on food security, income and asset index. Specifically, their study revealed that adoption of multiple stress tolerant crop varieties increased household dietary diversity by up to 11 percentage points, increased asset index by up to 60 percentage points and more than doubled household income per adult (equivalent to $140). The adoption of small ruminants also increased household dietary diversity scores by up to 10 percentage points and increased asset index by up to 51 percentage points.

A review of existing evidence of different sustainable land management practices aimed at increasing and stabilizing crop productivity in developing countries by Branca et al. (2011) revealed that soil and climate characteristics were key in interpreting the impact on crop yields and mitigation of different agricultural practices and that technology options which are most promising in enhancing food security at smallholder level are also effective on increasing system resilience in dry areas and mitigating climate change in humid areas. In Bangladesh, Mendola (2007) assessed whether adoption of modern seed technology by resource poor farmers improves their income and decreases the propensity to fall below the poverty line. Using non-parametric propensity score matching analysis, they found a robust positive effect of agricultural technology adoption on farm household wellbeing suggesting that there is a large scope for enhancing the role of agricultural technology indirectly contributing to poverty alleviation. Mukankusi et al. (2015) evaluated 21 bean varieties bearing different characteristics with over 300 farmers in replicated trials in the first season of 2012 and two seasons of 2013 respectively. They found that breeders and farmers look out for similar traits with yields being the major driver, and in most cases end up with the same result with few discrepancies.

A recent study by Teklewold and Mekonnen (2020), investigated the effects of a combination of climate smart agricultural practices on risk exposure and cost of risk using panel data from the Nile Basin of Ethiopia. Using a multinomial treatment effects framework by controlling weather variables for key stages of crop growth, they found that adoption of combinations of practices is widely viewed as a risk reducing insurance strategy that can increase farmers' resilience to production risk. They also reject the hypothesis of equality of

weather parameters across crop development stages. Using data from Niger, Asfaw et al. (2016) assessed the determinants of adoption of agricultural technologies under climate risk and evaluated their impact on food security. Using the multivariate probit and instrumental variable techniques to model adoption decisions and their impact, they found that adoption of modern inputs (inorganic fertilizers and improved seeds) and organic fertilizers is positively associated crop productivity and crop income. They also found that weather variability, household wealth, education, labour, distance to the nearest market and distance to nearest extension centres were some of the determinants of the type of practices adopted.

Overall, although there is a good number of studies on climate-smart agriculture in Kenya, a general overview reveals significant differences in applied definition, contextual factors and methodological approaches making comparison difficult. Most of the studies are also single case studies. This study therefore contributes to this literature using nine counties in Kenya as a case study.

CSA impact pathways

The main objective of CCAFS is to contribute to a climate resilient nation which is food and nutrition secure and that has equitable access to livelihood opportunities for all while improving natural resource systems and ecosystem services. This is to be achieved through promotion of climate smart agriculture to increase carbon storage in agricultural systems as well as reducing GHG emissions from food systems and agricultural value chains to mitigate climate change and supporting enabling policies and increased investments in agriculture and natural resource management. As per the CCAFS 2017-2022 phase II proposal, the aim was to reduce poverty by having 11 million farm households adopt CSA practices by 2022 through this action and policy engagement; improve food and nutrition security by providing a climate lens on the actions and interventions and using its climate smart village approach to test approaches in an integrated manner; and improve environmental health through technical development of mitigation options in collaboration with CGIAR research programmes.

The promotion of climate smart agriculture was aimed at addressing the persistent constraints and challenges in agriculture through innovative technologies and practices,

policies and enabling environments and conducive investments (Solomon et al. 2018). The major areas of action even in the CCAFS East Africa 2019-2021 strategy revolve around the four areas proposed in the CCAFS phase II proposal and borrowed from Lipper et al. (2014) which are mainly: building evidence; developing capacity of institutions and services; coordinating climate and agricultural policies; and stable strategic investment to reach scale. The impact pathway builds on the CCAFS phase II proposal and is further elaborated as per Figure 1 showing the baseline scenario and the stated interventions based on the four key interconnecting interventions. These are namely: testing, evaluating and increasing access to and promotion of climate smart technologies, innovations and policies; climate information, agro-advisory and insurance for climate risk management; working with governments, private sector and other non-state actors to raise awareness on low emissions development (LED) systems in crop and livestock sectors; and gender, youth and socially inclusive growth. Figure 1 presents the CCAFS envisioned impact pathways.

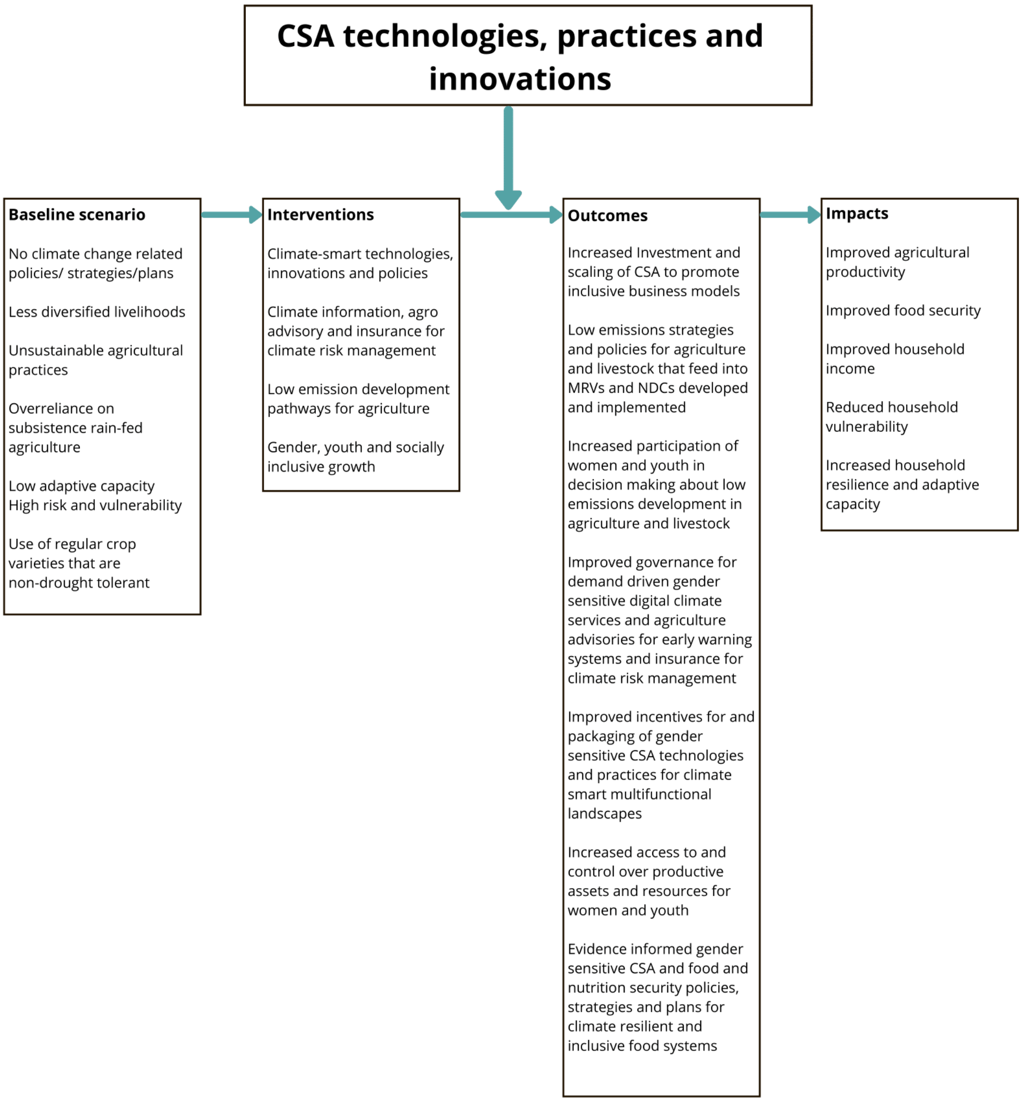

Figure 1. CCAFS envisioned impact pathways.

Source: Solomon et al. 2018

Chapter three

Methodological framework

The overall objective of the assessment is to assess how CCAFS engagement with the government has helped shape policy and CSA coordination efforts as well as an interest in understanding to what extent these policy changes have influenced farmers’ practices across the agricultural value chain. In order to assess the progress and achievements of the programme in addressing the objective, identify and document lessons and provide recommendations, both qualitative and quantitative approaches were employed.

A theory-based approach and mixed methods were employed in the assessment. This required an understanding of the specific processes and mechanisms through which the project interventions deliver impact. A thorough analysis of the theory of change in the CCAFS East Africa strategy 2019-2021 (Solomon et al. 2018) and the CCAFS phase II proposal was done in order to derive full understanding of the interventions. The theory-based approach helped examine how the program interventions were to deliver outcome and impact and then assess where the links at various results levels are weak or missing. Finally, the causal claim about the impact of the process linking program interventions with final outcomes was derived from theory, perceptions of stakeholders (mainly policy makers and key informants) and the household level analysis results.

The first step involved an extensive desk review of the CCAFS program documents, CCAFS relevant publications, outcome case studies, the CCAFS EA strategy in order to understand the CCAFS Theory of Change and how CCAFS's engagement in Kenya was expected to influence various policies and frameworks on climate change, agriculture and CSA. This also involved a review of the various government publications on climate smart agriculture e.g., NCCRS, NCCAP, KCSA, and KCSAIF. Various county CIDPs were also reviewed to assess the level of mainstreaming of climate change. The findings from the review guided development of research tools for use at household and policy level. The study also examined how CCAFS, NAMA, CIAT, ICRAF and the World Bank-funded KCSAP have influenced CSA at national and county level. The review findings were used for comparative purposes and to establish lists, patterns and trends. All such data/ records have been appropriately referenced in the study report. The next section presents the methodologies employed at policy and household level.

Policy makers' and other stakeholders' level

In-depth interviews with key informants (virtual interviews via Zoom, Webex and Teams) were conducted with government actors at national and county levels. This involved interviews with the Climate Change Directorate at the Ministry of Environment, Climate Change Unit at MOALFC, KCASP and Agriculture Sector Development Strategy Programme (ASDSP) officers at county level and head of any existing county climate change unit and department of agriculture. Finally, interviews were also held with some non-state actors at the national and county levels who are involved in CSA and climate change issues. The

interviews were meant to explore and validate findings from the desk review. The interviews also covered CCAFS engagement with government in development of the CSA strategy and implementation framework as well as in preparation of agriculture and gender submission for UNFCCC negotiations. Interviews were also conducted with relevant CCAFS scientists and partners as agreed by the CCAFS team. The aim of the key informant interviews (KIIs) was to find out policy makers' views, opinions, knowledge, experiences with the CCAFS's influence on CSA in Kenya. Thematic analysis was used to interrogate the themes emerging from the interviews. The findings from the KIIs informed the refinement of the final household questionnaire. A summary of the KIIs for policy interview is presented in Table 1.

Table 1. Key informants from state and non-state actors interviewed.

Entity	Target KII
State Departments	Ministry of Environment and Forestry, Climate Change Directorate; climate change unite- State Department for Crop Development; Climate Change Units -State Department for fisheries; Climate change desk officer: The National Treasury and Planning; State Department for Livestock, KFS, KALRO and NEPAD
Council of Governors	Agriculture desk officer
Counties 1. Narok, 2. Trans Nzoia, 3. Laikipia, 4. Homa Bay, 5. Tharaka Nithi, 6. Kakamega, 7. Isiolo, 8. Kilifi, 9. Nyeri	Director Agriculture (crop development), Director Livestock, Director Fisheries, Director Environment, local Chiefs, village elders
Non-State Actors	ILRI (CCAFS)

Household/farmers' level

The study employed a range of econometric modelling techniques to investigate the determinants of household adoption of CSA technologies as well as choice of CSA approach and the impact of the same on a range of outcome indicators. The study employed a probit regression model (Wooldridge 2010) to assess the determinants of adoption of CSA technologies and choice of CSA approaches.

Estimating the impact of CSA adoption

Analytical framework

The framework is grounded in Roy (1951) occupational choice model. We assume that households decide whether to adopt CSA technologies or practices based on utility

maximization. If a household expects to benefit from adopting the CSA practice then we assume they will adopt the practice. Assignment to treatment is therefore non-random. Define V_{ij} the utility of household i=1 2……N in treatment regime j= {0, 1}, with 1 representing adoption of CSA technologies and 0 otherwise. Therefore $D_i = 1$ if $V_{i1} > V_{i0}$. Similarly, Y_{ij} is defined as a vector of potential outcome variable (i.e., total value of agricultural yield, total value of livestock holding, and per capita household monthly expenditure). Where Y_{i1} is the potential outcome for adopters of CSA practices and Y_{i0} is the potential outcome for non-adopters of CSA practices. The difference between Y_{i1} and Y_{i0} can therefore be used to measure the differential impact on total yield of agricultural produce/value of agricultural produce, food security and per capita household expenditure/income.

According to Rubin (1973), program impact is the difference between the observed and the counterfactual outcome. The main challenge is that counterfactual is not observable and an individual cannot be in both states at the same time. A quasi-experimental approach is therefore more appropriate for identifying the counterfactual given that adoption of CSA practices is non-random. Controlling for adoption decision is therefore important in order to tease out the impact of CSA adoption. We consider that differences in potential outcome variable for CSA adopters can be due to unobserved heterogeneity. Failure to distinguish between the causal effects of adoption of CSA practices and effect of unobserved heterogeneity may lead to misleading conclusion and policy implication.

The study therefore adopts a combination of econometric methods, namely: the propensity score matching (PSM) to determine the effect of adoption of CSA practices on total value of agricultural yield, total value of livestock holding, and per capita household monthly expenditure. However, since PSM would yield biased estimates if there are unobservable determinants of adoption of CSA practices, we tested for endogeneity and extended the analysis by employing an instrumental variable (IV) approach and specifically Lewbel's Heteroscedasticity based instrumental variable approach that uses internally generated instruments in the absence of plausible instruments (Lewbel 2012).

Propensity score matching

Theoretical and analytical framework

The theoretical foundation follows Roy (1951) and Rubin (1973). The household decision to adopt CSA practices is assumed to depend on the anticipated benefits. The latter are proxied through the following outcomes: total value of agricultural yield, total value of livestock holding and per capita household expenditure. The main interest is the average treatment effect on the treated (ATT). However, it is not possible to estimate the ATT by simple difference of the above metrics because it is not possible to observe what the metrics would have been without adoption of CSA practices (treatment) and also because assignment to treatment is also non-random. Quasi-experimental approaches therefore suffice. The self-selection and missing data problem will therefore be solved first using the propensity score approach. The latter involves using non-adopting households as comparison or counterfactual units.

The units must be similar in a variety of observable characteristics that are summarized in their propensity scores. Assuming a set of observable covariates X, which are unaffected by adoption of CSA practices (treatment), potential outcomes can be said to be independent of treatment assignment, if two conditions are met, i.e., conditional independence assumption (CIA) and that there exist adequate units of analysis in the common support (the overlap condition) (Khandker et al. 2009). The two conditions rule out the phenomenon of perfect predictability of treatment given X:

$$(Overlap): 0 < P(T = 1|X) < 1$$

The condition ensures that households with same X values have positive probability of being both adopters and non-adopters of CSA practices (Heckman et al. 1999).

Estimation of ATT is undertaken in two steps. The first step is the estimating of propensity scores from probit model using household and farm level characteristics. The score indicates the probability of either being an adopter or non-adopter of CSA practices. The scores are used to identify the control groups by matching the adopters and non-adopters according to their propensity scores using a range of matching methods. The second step then involves estimating the ATT of households adopting CSA practices on the three outcome measures using the matched observations.

Model specification

The PSM estimator for the ATT is specified as the mean difference in Y (total value of agricultural yield, total value of livestock holding and per capita household expenditure) over common support, weighting the comparison units by the propensity score distribution of participants. The cross-section estimator is then specified as:

$$\tau_{ATT}^{PSM} = E(P(X)|T = 1)\{E[Y(1)|T = 1, P(X)] - E[Y(0)|T = 0, P(X)]\}$$

Where Y(1) and Y(0) represents total value of agricultural yield, total value of livestock holding and per capita household monthly expenditure for adopters and non-adopters of CSA practices respectively. T=1 indicates CSA adopters and T=0 indicates CSA non-adopters whereas X denotes the household and farm characteristics. However, it is important to note that PSM has several weaknesses such as the restrictive assumption (CIA), selection issues and potential endogeneity. Two potential sources of endogeneity that might bias the result will be identified. First is the presence of unobserved household heterogeneity that influences both adoption and the potential outcomes. This can be controlled for with household fixed effects (Michler et al. 2019). Second is the possible presence of unobserved time varying shocks that might affect a household's access to and use of CSA practices while being correlated with the outcome measures. Since PSM cannot address such potential endogeneity and also has a restrictive assumption (i.e., Conditional Independence Assumption), sensitivity analysis of the PSM estimates was therefore first conducted. This informed the use of Lewbel's Heteroscedasticity-based Instrumental variable approach (Lewbel 2012) that uses internally generated instruments to assess the robustness of PSM estimates.

Instrumental variable approach

The IV approach seeks to address challenges in employing standard IV methods employed in linear regression models, e.g., $Y = X\beta + \mu$, where we experience violations of the zero conditional mean assumption $E[\mu|X] = 0$. Such IV models rely on availability of suitable instruments to identify the model via exclusion restrictions. The instrument Z subsequently has to satisfy the following conditions: Orthogonality condition, i.e., $E[\mu|X] = 0$; must be correlated with the X's; and properly excluded from the model, so that they only affect the outcome variable indirectly.

The greatest challenge therefore in IV estimation is getting instruments which satisfy the three conditions concurrently. Lewbel's Heteroscedasticity Based Instrumental variable approach therefore comes in handy to identify structural parameters in regression models with endogenous or mismeasured regressors in the absence of traditional identifying information such as external instruments or repeated measurements (Lewbel et al. 2012).

Lewbel's Heteroscedasticity based instrumental variable approach: Analytical framework

Consider observed endogenous variables Y_1 and Y_2, X a vector of observed exogenous regresors, and $\varepsilon = (\varepsilon_1, \varepsilon_2)$ as unobserved error processes. Consider a structural model of the form

$$Y_1 = X_0\beta + Y_2\gamma_1 + \varepsilon_1$$

$$Y_2 = X_0\beta + Y_1\gamma_2 + \varepsilon_2$$

This system is triangular when $\gamma_2 = 0$ (or with renumbering, when $\gamma_1 = 0$). Otherwise, it is fully simultaneous. The errors $\varepsilon_1, \varepsilon_2$ may be correlated with each other. If the exogeneity assumption $E(\varepsilon X) = 0$ holds, the reduced form is identified, but in the absence of identifying restrictions, the structural parameters are not identified. These restrictions often involve setting certain elements of β_1 or β_2 to zero which makes instruments available.

Identification in Lewbel's approach is achieved by restricting correlations of $\varepsilon\varepsilon'$ with X. This relies upon higher moments and is likely to be less reliable than identification based on coefficient zero restrictions. However, in the absence of plausible identifying restrictions, this approach may be the only reasonable strategy.

The parameters of the structural model will remain unidentified under the standard homoscedasticity assumption: that $E(\varepsilon\varepsilon'|X)$ is a matrix of constants. However, in the presence of heteroscedasticity related to at least some elements of X, identification can be achieved.

In a fully simultaneous system, assuming that $cov\left(X, \varepsilon_j^2\right) \neq 0$: $j = 1; 2$ and $cov\ (Z, \varepsilon_1\varepsilon_2) = 0$ for observed Z will identify the structural parameters. Note that Z may be a subset of X, so no information outside the model specified above is required. The key assumption that $cov\ (Z, \varepsilon_1\varepsilon_2) = 0$ will automatically be satisfied if the mean zero error processes are

conditionally independent: $\varepsilon_1 \perp \varepsilon_2 | Z = 0$. However, this independence is not strictly necessary.

This approach is crucial especially where there is some evidence of spill-over effects among the control groups. Research has also shown that failure to address spill-over effects can lead to under or overestimation of the impact (Abadie et al. 2002).

Definition and measurement of variables

The desk review of the programme documents and government publications helped in identification of the CSA interventions at the devolved level. The study used a range of outcome variables, namely: total value of agricultural yield, total value of livestock holding and per capita household expenditure. Total value of agricultural yield was used to capture access to food while total value of livestock holding was employed as most rural households save their earnings from agricultural crop production in livestock which is also a symbol of wealth in the villages. The value of agricultural yield was therefore obtained by multiplying the unit price of the various agricultural products with the quantity produced and summing up. The focus on agricultural yield was on major products such as maize, beans, potatoes, peas, sorghum, and sale of animal products (milk, meat, etc.). Total value of livestock holding were obtained by getting the sum of the unit price of each animal with number of livestock (goats, sheep, cows, camels, etc.). This was further guided by the counties identified. The choice of various outcome measures was due to the heterogenous nature of counties. It is important to note that valuation of livestock holding and agricultural yield were just approximations. Most households were not able to give exact figures. The prices of the same also varied with season. We therefore decided to use an average estimate to capture both seasons.[10]

Household welfare is measured by per capita monthly expenditure. Per capita monthly expenditure was preferred to household monthly income since households are prone to under reporting their monthly income. The income may also have fluctuated given that the interview was conducted in the aftermath of COVID-19 effects. The choice of per capita

[10] We noted during the field work that when schools open, the value of livestock is normally very low as most households sell their livestock to take kids back to school. The prices of agricultural produce also tend to be low during harvest season due to high supply.

expenditure is also easily interpreted and provides information over the consumption bundle that fits within the household budget although this may be affected by micro finance institutions that are enabling easy access to credit facilities among village households or smaller women's groups known as "chamas" (Okumu and Muchapondwa 2020). Monthly expenditure is also preferred due to ease of recall. The expenditure was aggregated household spending on food supplies, education, farming and livestock, clothing and apparels, medical and other miscellaneous items.

The interventions or CSA practices were grouped into five categories, namely: crop management practices (growing drought resistant crops/multiple stress tolerant crops such as sweet potatoes and cassava, crop rotation, changing planting dates following rain, sequential cropping, multi-season cropping, intercropping); land management practices (use of terraces/land contours, stone gabions, planting trees on crop land, use of live fences, adoption of cover crops in farm); farm risk reduction practices (diversified crop/increased range variety of farm crops, irrigation, use of weather forecast (agro-weather information), insurance (crop and livestock insurance)); soil and water conservation practices (planting food crops on tree land/agroforestry, use of mulching, rain and flood water harvesting, application of organic manure, integration of legumes (nitrogen fixers), efficient use of inorganic fertilizers); and livestock management practices (use of plastic silos for post-harvest fodder management, use of muskan milk containers, diversified animal breeds, use of improved livestock breeds, feeds and feeds management/fodder banks).

Other controls were household sociodemographic profiles such as age of household head, gender, income sources, economic activities, farm and contextual variables as well as elevation, soil type, and climatic variables etc. We control for policy level interventions by including dummies for presence of KCSAP project, whether a household was contacted by county on CSA, and whether a household has been trained on CSA practices by the county or any national government institutions or NGOs and also include interaction terms in some models.

Survey design and data collection methods

Sampling design

The study used primary dataset, collected in the months of October and November 2020. A multi-stage sampling technique was adopted. At the household level, the sampling frame for this study included farmers, fisher folks and pastoralists in selected counties whether adopting CSA technologies or not. PSM requires data for both the treatment group (adopters of CSA technologies) and control group (non-adopters of CSA technologies). Both samples must be larger than the sample size suggested by power calculations since observations outside the region of common support are discarded. Generally, oversampling must be greater for the potential comparison group than for the treatment group.

The first step of sample selection was identification of counties. Counties were purposively selected based on the agro-ecological zones (AEZs)[11] and regional representation. According to FAO (1996) an agro-ecological zone is a land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover having a specific range of potentials and constraints for land use. The AEZs are upper highlands, upper midlands, lowland highlands, lowland midlands, inland lowlands and coastal lowlands. A list of the AEZs in Kenya and the sampled counties is presented in Table 2.

Table 2. Agro-ecological Zones in Kenya and the sampled counties.

Agro-Ecological Zones	Counties	Selected Counties
Upper Highlands	Murang'a, Meru, Nyandarua, Nyeri, Nakuru, Elgeyo Marakwet	Nyeri
Upper Midlands	Machakos, Nyamira, Narok, Vihiga, Kisii Kirinyaga, Kiambu, Trans Nzoia	Narok, Trans Nzoia
Lowland Highlands	Laikipia, Uasin Gishu, Nandi, Kericho	Laikipia
Lowland Midlands	Tharaka Nithi, Kakamega, Homa Bay, Kisumu, West Pokot, Embu, Busia, Bungoma, Siaya, Migori, Kajiado Kitui, Makueni, Taita Taveta, Bomet	Kakamega, Homa Bay, Tharaka Nithi

[11] An Agro-Ecological Zone is a land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover and having a specific range of potentials and constraints for land use (FAO 1996)

Inland Lowlands	Baringo, Isiolo, Turkana, Marsabit, Garissa, Tana River, Wajir, Samburu, Mandera	Isiolo
Coastal Lowlands	Lamu, Kilifi, Kwale	Kilifi

Source: Africa Women Studies Centre and KNBS (2013)

Based on the AEZs, a total of 9 counties were purposively identified: Kakamega (Western), Kilifi (Coast), Tharaka Nithi and Isiolo (Eastern), Homa Bay (Nyanza), Nyeri (Central), Narok, Laikipia and Trans Nzoia (Rift Valley). The purposive sampling of counties avoided sampling Climate Smart Village counties such as Kericho, Kisumu (Nyando) and Makueni (Wote).

The second step was determination of number of households per county. A stratified random sampling technique was adopted. This step involved determination of the total sample size for the entire study then using proportionate sampling to determine sample size per county and the second step was to determine the sample size per sub-county (the study sampled at least three sub-counties per county). This was to ensure adequate representation in terms of geographical/climatic conditions and population per county. The third step was to determine the sample size per enumeration area in each sub-county identified. Within each sub-county, we identified an enumeration area (an administrative location headed by chiefs) and used the list of households at the chief's office to randomly select households into the study.

Sample size determination

First, the sample size must cater for the statistical significance (assumed at 95%, Z=1.96), margin of error (e=5%), estimated variance in the population as decimal (p=0.5, q=1-p).

Using the statistical sample size formula as proposed by Cochran (1963) ($n = \frac{Z^2pq}{e^2}$).

$$n = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 385\ households$$

Table 3. Distribution of households sampled by county.

County	Number of Households (2019 Census)a	Sample Proportion	Approximate Sample size	Number of Households sampled	Response Rate
Nyeri	248,050	110.3043084	111	85	76.57%

Narok	241,125	107.2248593	108	85	78.70%
Trans Nzoia	223,808	99.52423562	100	78	78.00%
Laikipia	149,271	66.37869145	67	76	113.43%
Kakamega	433,207	192.6409938	193	74	38.34%
Homa-Bay	262,036	116.5236837	117	72	61.54%
Tharaka Nithi	109,860	48.85318007	49	60	122.44%
Isiolo	58,072	25.82379276	30	39	130.00%
Kilifi	298,472	132.7262549	133	103	77.44%
Total	2,023,901	900	908	672	

Source: KNBS 2019

Assuming a non-response rate of 25%,[12] the final sample size was estimated at (385/0.75) = 514 households. However, we preferred to have significant number of both categories (adopters and non-adopters) into the study for sufficient abstraction from the two groups based on socio economic trends. To ensure sufficient control we increased the total sample size from 514 to approximately 672 households that will be proportionately distributed among the nine counties sampled. Using proportionate sampling the total sample size per county is therefore summarized in Table 3. The table shows that Kakamega county was under sampled; this was attributed to the adverse weather conditions that hindered movement and mechanical breakdowns.

Data collection procedure

A mixed method approach comprising both qualitative and quantitative data collection methods was employed. The use of a mixed method approach helps in strengthening and expanding the study's conclusion and heightening its validity (Schoonenboom and Johnson 2017). Household level and policy level data were collected during the months of October and November 2020. Household surveys were administered to collect data regarding

[12] We assumed a non-response rate of 25% due to the COVID-19 pandemic. This was done taking into consideration that at some point in time, rural communities were very hostile to people from Nairobi since they believed COVID-19 was being spread by Nairobians. This was therefore just a precautionary measure.

household demographic and socioeconomic profiles, extension and information services, housing, sanitation, water and energy, market information services, land ownership and utilization, agricultural activities, household food security, climate and geographic variables. The household survey had a duration of approximately 45 minutes. The policy makers' level survey and other non-state actors' survey had a duration of 20 minutes. Qualitative data were collected through focus group discussions (FGDs), in depth interviews with key informants, case studies/stories and field observations during the household visits. On the other hand, quantitative data were collected through in-depth household interviews with farmers. Approximately three FDGs were held per county comprising of 7-8 persons. The FGDs gave information to strengthen findings from the household interviews and were mainly qualitative in nature exploring the farming practices and nature of support from national or county government towards promotion of CSA technologies.

Households were randomly selected from the register of households at the chief's office. The chief then designated village elders to take the enumerators and research assistants to the identified households. In cases where the household head or an adult were not at home the next neighbouring household was selected for interviews. However, this was a very rare occurrence since most rural households were in the farms or at home and in some cases where the household head was not available, the wife was always present. The household members were generally very cooperative in providing required information since the village elders always introduced the teams. It is important to note that some agricultural produce was very difficult to quantify especially at the village level, but much effort was made to make the questions easy. The other challenge was translation of the questions into local language. The village elders however made the task easy for locals.

At the household level, a total of 672 households were interviewed from the nine counties. A distribution of the households by county is presented in Table 3. Data were collected from all households regardless of whether adopter or non-adopters of CSA. Supplementary data on climate change, geographical variables and farm and household characteristics and CSA practices and technologies were also collected from households sampled. The study revealed that various CSA technologies have been widely adopted by households, i.e., at least every household adopted a technology. The analysis within the study employed both

household level and policy makers' level data. However, information obtained from KIIs, focus group discussions, field observations and case stories helped contextualize the results.

Ethics and approval

Ethics approval for the study was sought from ILRI's Institutional Research Ethics Committee, and a research permit was also obtained from the Kenya National Commission for Science, Technology and Innovation (NACOSTI). Permission was also sought from the county commissioner in each of the nine counties and from local area chiefs. The farmers to be interviewed were also asked for their consent first before commencement of the interviews.

Chapter four

Results and discussions

This section presents the results of the study including findings from the KIIs with policy makers and empirical results from the household interviews using various approaches. The first section presents a summary of the KII findings followed by summary statistics and then the ordinary least squared, PSM followed by Lewbel's Heteroscedasticity based instrumental variable approach.

Policy level interventions: Findings from the KIIs and FGDs

At the national level, the Multi-Stakeholder Platform consisting of government, public, private, research, academia, farmer organizations, CSOs, development partners working on CSA with the Ministry of Agriculture Livestock, Fisheries and Cooperatives (MOALFC) Climate Change Unit (CCU) as the coordinating agent has been instrumental in promoting CSA practices at the national level despite the short time. This could be concerning issues of technical and financial support from the various partners in the platform. The KIIs at the national level revealed that a collaboration between CIAT, CCAFS, ILRI, ICRAF and Mazingira Institute and development partners such as GIZ, USAID, JICA, UNDP, FAO and the World Bank supported various national government departments (i.e., State Department for Agriculture, State Department for Livestock, State Department for Fisheries and Blue Economy and the State Department for Irrigation) leading to production of various policy documents, namely: National Climate Change Response Strategy, National Climate Change

Action Plan, National Adaptation Plan, Nationally Determined Contribution, Kenya Climate Smart Agriculture Strategy, Green Economy Strategy and Implementation Plan, development of UNFCCC country positions and submissions on agriculture and gender for the UNFCCC. Most of these strategies are disseminated through workshops with county governments who are expected to cascade them further to farmers through Information Education and Communication (IEC) materials, field demonstrations and workshops and sensitization meetings. However, from the FGDs with farmers, we found that about a third of the population had heard of CSA or know about CSA. Those who had heard it was mostly through local radio stations, television programmes and few trainings and workshops conducted mostly by NGOs as well as field demonstrations. In some counties like Narok all the FGDs held revealed that none had knowledge of CSA nor had heard about CSA and therefore a low uptake of modern CSA technologies. This was also the case in certain sub counties in other counties. This shows that there is need for county-specific interventions instead of a one-size-fits-all approach like it is currently.

Most of the state departments have also collaborated with CCAFS in development of climate change policies and plans, capacity building of stakeholders on climate change and participation in UNFCCC climate change negotiations.

Research outputs from the collaboration between national state departments and research institutions normally inform modelling future scenarios and applying the same for proactive planning such as NDCs and Medium-Term Plans as well as formulation of County Integrated Development Plans (CIDPs). Climate change lenses are also currently applied in research processes. The national government has also encouraged involvement of private sector actors in development of climate change related market information services and products to sustainably transform agriculture through provision of legal and legislative frameworks and support to private sector to develop bankable project proposals. However, a major challenge that has hindered promotion of CSA from the national to the county level is the politics of agriculture as a devolved function and breakdown of the reporting structures from the grassroots to get accurate data.

The KIIs with national and county government officials revealed that the collaboration between national and county government is wanting because agriculture is a devolved

function. Further, the promotion of national level CSA interventions at county level is implemented through former agricultural officers who were inherited by county government after devolution hence it is more of a good will and the officers can refuse since they are now employees of the county. However, the arrangement has somehow worked though when it comes to disbursement of finances for any activity say crop insurance or engagement of communities through workshops. The finances are picked from the national government ministry by a national ministry official who goes to the ground to disburse the funds with support from the county agriculture officer. It was also revealed that the national government is planning to post liaison officers to the county level to handle national government functions. This implies that the coordination arrangement will further be worsened since counties will also be running parallel similar programs. It is therefore evident that there is weak coordination of CSA practices from national to county level and is set to worsen if left unchecked as the national government is unwilling to send funds directly to county governments to support agricultural activities. It was also noted that national government engagement with communities at the county level have often been prone to elite capture where only the elites who access the information frequently attend unlike when it is coordinated by counties where county assembly members and ward administrators spread the information across the entire location. This calls for strengthening the Multi-Stakeholder Platform to improve coordination of agricultural activities and data flow and accuracy and exploring ways of integrating the two levels of government.

The FGDs with smallholder farmers also revealed that most contact with smallholder households on CSA has been with NGOs (such as Caritas, Red Cross, One Acre Fund, Amiran and Syngenta, among others), although a good proportion have also been contacted by county government officials. County governments have been supportive in some counties by providing subsidized fertilizers and seeds but one has to register. The channel of communication on subsidy provision in some counties is also unclear since most announcements are made at funerals hence most households miss and is also prone to elite capture. There is also no fairness in distribution of inputs (mainly seeds and fertilizers). We witnessed one seed distribution function in Isiolo county during the field work. Some counties also do farm demonstration especially cotton farmers in Homa Bay. Counties like Homa Bay have also benefited from distribution of banana suckers, jembes (hoes), pangas

(machetes), wheelbarrows and championing soil and land conservation through terraces and trenches as well as field demonstrations with support from the Kenya Agricultural and Livestock Research Organization (KALRO) and MOALFC. It is also important to note that in some sub counties such as Narok, there has never been contact whether with NGOs or either level of government on issues of CSA.

One of the outcomes of the national engagements is the Kenya Climate Smart Agriculture Project (KCSAP).[13] Out of the nine counties sampled in the study, only five counties benefitted from the project: Nyeri, Laikipia, Isiolo, Tharaka Nithi and Kakamega. A number of counties also have climate change policies (Tharaka Nithi and Homa Bay), Climate Change Units (Tharaka Nithi, Homa Bay and Kakamega) while only Tharaka Nithi and Isiolo have a climate change fund. Some counties such as Tharaka Nithi have a Climate Change Act and climate change response strategy. Although counties were hardly aware of CCAFS they said that most of the practices at the county level were being borrowed from national level implying that without CCAFS most of the policies at national and county levels would not have been in place. The multi-stakeholder platforms have also provided grounds for engagement that have benefited various institutions in diverse ways especially in terms of select projects. It is important to note that Schedule Four of the Kenya Constitution highlights that national government will play key role in providing technical support to counties. Therefore, any policy developed by national government they have to support counties to come up with county specific policies on the same and align to the national government policy. This implies that the national policies will also be implemented at the policy level. The same happens in all planning documents where the CIDPs have to be aligned to the national plans such as the Medium-Term Plans (MTPs).

The expectation is that such interventions from national level through counties should trickle down to the household level. However, at the household level, we found that households had stuck to the traditional crop management and land management CSA practices as

[13] KCSAP is a 5-year (2017-2022) Government of Kenya project jointly supported by the World Bank under the framework of the Agriculture Sector Development Strategy (ASDS) (2010-2020) and national Climate Change Response Strategy (2010). The project aimed at increasing agricultural productivity and enhancing resilience/coping mechanism to climate change risks in the targeted smallholder farming and pastoral communities in Kenya. The key components of the project are: upscaling CSA practices; Strengthening CSA Research and Seed Systems; Supporting Agro-weather, Market and Advisory Services; Project coordination and Management; and Contingency Emergency Response.

described in the household level results. The traditional CSA practices in this study refers to those that households have been doing since time immemorial for instance use of organic manure, inter cropping, agroforestry, crop rotation, etc. The predominant CSA practices that the county governments have been promoting are mainly: minimum tillage; planting drought tolerant/early maturing crops; agroforestry; water harvesting for crop production; irrigated agriculture/solar irrigation; organic farming; crop insurance; and establishment of conservation structures among others. However, despite the promotion of such initiatives, most smallholder households at the county level still practice CSA practices such as: irrigation from boreholes and rivers, sack farming, use of drought resistant crops, changing planting dates, mixed cropping, manure and fertilizers, terrace and contours, delaying planting due to weather advisory, crop rotation, and tree planting. The most effective CSA practices were mainly improved varieties, on-farm soil and water management, runoff harvesting and conservation agriculture among others in small scale as revealed from the KIIs and FGDs.

Counties have further been upscaling adoption of CSA practices through capacity building on CSA technologies, provision of drought tolerant/early maturing crop variety seeds for bulking, supporting commercial fruit tree nurseries and excavation of water pans for vegetable production through irrigation. The knowledge on CSA has also been transferred through field demonstrations, workshops/barazas, TV programmes (Shamba Shape Up) and provision of IEC materials. The integration of CSA has also been aligned to the county plans to a large extent in most counties. However, knowledge about CCAFS is very limited at the county level although most of the county interventions target women and youth groups and strive to ensure that the one-third gender rule (part of the Kenyan Constitution) is complied with. National government has also been supporting counties through mainly projects implemented in collaboration with KCSAP, KALRO, CRAL, NARIGP, AFA, and KMD.

In research, counties have been partnering with various universities such as JKUAT, Meru University, Egerton University, University of Nairobi and Chuka Universities, KALRO, ICRAF, CETRAD, Kenya Seed Company, and Agri Seed Company and national government departments such as State Department for Water, State Department for Interior, State Department for Crops, State Department for Fisheries, National Drought Management Authority, National Environment Management Authority, Kenya Meteorological

Department, Kenya Forest Service, and Lake Basin Development Authority. Non-state actors such as IFAD, Caritas, Islamic Relief, Red Cross, Catholic Relief Services, World Bank, USAID, WFP, SIDA, UNDP, EU, SNV, GIZ, FAO, ASDSP II, AGRISS and World Vision have also been supportive in a number of counties.

The study also found that marketing of agricultural produce has remained a major challenge since most smallholder farmers use brokers who exploit them. Other challenges smallholder farmers still face include: price fluctuations, lack of transport and bad roads especially during rainy seasons. Brokers also tend to dictate the prices since they most of the time provide farmers with inputs, hence once produced they deduct the cost of production when paying farmers. The brokers also tend to dictate the packaging, prices and grading. Another major problem is the influx of cheaper farm produce from neighbouring countries such as Uganda and Ethiopia. In addition, at times there is no market and most goods are perishable making farmers sell them at throw away prices. This thus implies that there is need for encouragement of farmers to join cooperatives or marketing societies or to engage in contract farming to get markets for their produce and hence improve their livelihoods. A good experience was in Kabondo sub-county in Homa Bay; farmers reported that after the CSA training by KALRO they now get bumper harvests. In return, the community formed a sweet potato CBO (cooperative society) to solve marketing challenges faced by sweet potato farmers. Over 10,000 farmers are now engaged in sweet potato farming in Kabondo as the market is readily available through the CBO. Overall, despite the challenges in most counties, most farmers agreed that their welfare had improved compared to before training.

On the other hand, in terms of information access, farmers revealed that most agricultural advisory services they received through local radio stations and TV stations and at times farm visits or field demonstrations and group meetings in some counties. Agro-weather information is also often communicated through vernacular radio stations. This information is often about 70-80% accurate and has been useful in giving direction on farming. However, it was noted that counties that do not have access to local radio channels relied on general weather information which is not often accurate as it is not county specific. The early warning advisories have been received positively in most counties and have been helpful in planning. The success of this has been the spread of such information through social media and through farmer groups. Some of the challenges that have hampered adoption of CSA in

some counties have been lack of knowledge and training on CSA. Respondents in counties like Narok wondered that at the moment the produce is moderate yet they have zero knowledge on CSA; what would happen if they were empowered with the right CSA skills? Another challenge highlighted by smallholder farmers is lack of financial resources. It was also noted that there are no agricultural extension services nowadays since most extension services are provided at the shopping centres on so-called clinic days. However, not all farmers can afford to go to markets on those days.

From the key informant interviews and FGDs, we can conclude that to increase adoption of CSA technologies at the grassroots, there was need to sensitize farmers on benefits of CSA adoption, increased demonstration and more investment in extension service delivery, input subsidies, matching grants to purchase farm inputs and organization of farm demonstrations on CSA at the community level. However, this is likely to be hampered with inadequate extension staff and inadequate funds. Counties suggested setting aside at least 10% of the budget towards agricultural extension services.

Summary statistics

To determine the adopters of CSA practices, the study constructed an additive index of CSA practices summing up all the CSA practices as classified under crop management, land management, farm risk reduction, soil and water conservation and livestock management practices. We first run a correlation matrix of all the CSA practices. Since there was no problem of serial correlation, we preferred to construct an additive index as opposed to Principal Component Analysis (PCA) or factor analysis to avoid loss of some information. This constituted a total of 26 practices. This implies a household with a score of 26 adopts all the CSA practices. To determine adopters and non-adopters of the CSA practices, the study classified households that had 50% or more of the practices as adopters and below 50% as non-adopters.[14] This revealed that 236 households were considered adopters of CSA practices and 436 households' non-adopters of CSA practices. This assumed that some of the CSA practices adopted by households could be the traditional practices therefore those

[14] Although the threshold could be high for smallholder farmers, this was based on the fact that most CSA practices explored in this study were those that mostly required skills and physical energy. The FGDs revealed that most farmers just picked the skills from fellow farmers since most have not been trained.

adopting 13 practices and above are the main adopters of CSA. This approach would also reduce the loss of information if we condensed the practices based on PCA or factor analysis. This assumption is supported by findings from the FGDs where some communities claimed that at the moment, they are doing fine with practices they found their forefathers doing and wondered how they would be if they received just a little training.

Summary statistics of household socioeconomic and demographic profile are presented in Table 4. As expected, per capita monthly expenditure and total value of agricultural yield were higher for adopters of CSA practices compared to non-adopters. However, the total value of livestock holding was higher for non-adopters. A summary of the socioeconomic and demographic profile of the respondents also shows that overall, 80% of the respondents were males, of which 68% were household heads with a mean age of 49 years. About 79% were also married and with a minimum of 9 years of education. The average household size was six people with an average of three adults and three children. However, the average per capita monthly expenditure was found to be Ksh. 4,486 respectively and total agricultural yield to average about Ksh.75,485. In addition, it was also revealed that only 23% agreed that the county government gets in touch with them on matters of CSA practices while only 10% had received training on CSA practices. A description of the other variables is presented in Table 4.

Table 4. Summary statistics.

Variable	Whole sample			Adopters of CSA			Non-adopters of CSA		
	N	Mean	Sd	N	Mean	sd	N	Mean	sd
Dependent variables									
Total value of livestock holding	672	1.763e+06	1.510e+07	236	1.594e+06	5.216e+06	436	1.855e+06	1.840e+07
Total Value of Agric yield	672	75485	481438	236	133680	764341	436	43985	197707
Per capita monthly expenditure	672	4486	4787	236	5847	5856	436	3749	3908
Explanatory variables									
Age of HH head (years)	672	49.03	14.57	236	49.75	13.20	436	48.64	15.26
1 if HH sex is male	672	0.802	0.399	236	0.847	0.360	436	0.778	0.416
1 if HH head is married	672	0.790	0.407	236	0.881	0.324	436	0.741	0.439
HH head years of education	672	9.310	5.288	236	11.11	4.626	436	8.335	5.373
HH number of children	672	2.735	2.316	236	2.322	2.060	436	2.959	2.416
HH size	672	5.948	2.422	236	5.771	2.355	436	6.044	2.455
HH Monthly Income	672	29143	35286	236	42380	50593	436	21978	19783
1 if primary activity of HH is Agriculture	672	0.619	0.486	236	0.581	0.495	436	0.640	0.481
Number of Agric Extension visit	672	0.632	5.250	236	1.203	7.364	436	0.323	3.599
1 if HH experienced hailstorm	672	0.649	0.478	236	0.818	0.387	436	0.557	0.497
1 if HH member of local group	672	0.655	0.476	236	0.686	0.465	436	0.638	0.481
1 if HH head employed	672	0.686	0.464	236	0.894	0.308	436	0.573	0.495
1 if HH head own smartphone	672	0.531	0.499	236	0.682	0.467	436	0.450	0.498
1 if HH head has access to loan	672	0.586	0.493	236	0.797	0.403	436	0.472	0.500
1 if HH has crop insurance	672	0.0446	0.207	236	0.0720	0.259	436	0.0298	0.170

1 if HH has livestock insurance	672	0.0476	0.213	236	0.110	0.314	436	0.0138	0.117
1 if HH received Agric Infor	672	0.568	0.496	236	0.733	0.443	436	0.479	0.500
1 if HH received weather infor	672	0.615	0.487	236	0.809	0.394	436	0.509	0.500
1 if HH was visited by agrix ext	672	0.135	0.342	236	0.258	0.439	436	0.0688	0.253
1 if HH received input subsidy	672	0.162	0.369	236	0.212	0.409	436	0.135	0.342
1 if county contact on CSA	672	0.228	0.420	236	0.267	0.443	436	0.206	0.405
1 if HH experienced insuff rain	672	0.402	0.491	236	0.284	0.452	436	0.466	0.499
HH land size (Acres)	672	3.396	8.585	236	4.186	11.07	436	2.968	6.850
1 if HH head is a native	672	0.765	0.424	236	0.742	0.439	436	0.778	0.416
1 if HH head heard of CSA	672	0.399	0.490	236	0.466	0.500	436	0.362	0.481
1 if HH trained on CSA	672	0.106	0.308	236	0.119	0.324	436	0.0986	0.298
Distance to livestock market (km)	672	7.013	6.264	236	4.828	4.449	436	8.195	6.771
Distance to county office (km)	672	23.00	17.91	236	22.11	17.52	436	23.48	18.12
Distance to crop market (km)	672	4.544	5.061	236	4.189	3.371	436	4.736	5.768
1 if HH crop farmer	672	0.8199	0.3845	236	0.9661	0.1814	436	0.7408	0.4387
1 if HH is livestock farmer	672	0.9003	0.2998	236	0.9449	0.2286	436	0.8761	0.3298
1 if HH is mixed farmer	672	0.7470	0.4350	236	0.9449	0.2286	436	0.6399	0.4806
1 if HH is a fish farmer	672	0.0833	0.2766	236	0.1059	0.3084	436	0.0711	0.2573

The study also revealed that about 90% of the sampled households were livestock farmers, 82% crop farmers and 75% mixed farmers, whereas only 8% practiced fish farming. A summary of the CSA practices adopted by farmers in the nine counties is presented in Table 5. The results revealed that the predominant CSA practices are: application of organic manures (76.8%); intercropping (71.0%); changing of planting dates (68.3%); efficient use of inorganic fertilizers (64.3%); multi season crop (64.4%); use of live fences (63.2%); use of terraces (64%); use of weather forecast (58.3%); drought resistant crops (59.5%); and planting trees on crop land (54.3%) (see Table 5). Overall, we found that predominant CSA practice was crop management practices revealing that most household tend to use the traditional CSA practices.

Table 5. Summary of climate-smart agriculture practices.

Group	CSA practices	Whole Sample			Male			Female		
		N	mean	Sd	N	Mean	Sd	N	mean	Sd
Crop Management Practices	Drought resistant crops	672	0.595	0.491	539	0.636	0.481	133	0.429	0.497
	Crop Rotation	672	0.454	0.498	539	0.512	0.500	133	0.218	0.414
	Changing planting dates	672	0.683	0.466	539	0.688	0.464	133	0.662	0.475
	Sequential cropping	672	0.131	0.338	539	0.152	0.359	133	0.0451	0.208
	Multi season cropping	672	0.644	0.479	539	0.686	0.464	133	0.474	0.501
	Intercropping	672	0.710	0.454	539	0.735	0.442	133	0.609	0.490
Land management practices	Use of terraces	672	0.640	0.480	539	0.651	0.477	133	0.594	0.493
	Stone gabions	672	0.0893	0.285	539	0.0835	0.277	133	0.113	0.318
	Planting trees on crop land	672	0.543	0.499	539	0.570	0.496	133	0.436	0.498
	Use of live fences	672	0.632	0.482	539	0.649	0.478	133	0.564	0.498
	Adoption of cover crop	672	0.295	0.456	539	0.315	0.465	133	0.211	0.409
Farm risk reduction practices	Diversified crops	672	0.421	0.494	539	0.473	0.500	133	0.211	0.409
	Irrigation	672	0.185	0.388	539	0.202	0.402	133	0.113	0.318
	Use of weather forecast	672	0.583	0.493	539	0.631	0.483	133	0.391	0.490
	Insurance (livestock and crop)	672	0.0580	0.234	539	0.0501	0.218	133	0.0902	0.288
Soil and water conservation practices	Planting food crops	672	0.244	0.430	539	0.301	0.459	133	0.0150	0.122
	Mulching	672	0.229	0.421	539	0.241	0.428	133	0.180	0.386
	Rain and flood water harvesting	672	0.406	0.491	539	0.391	0.489	133	0.466	0.501

	Application of organic manure	672	0.768	0.423	539	0.777	0.416	133	0.729	0.446
	Integration of legumes	672	0.490	0.500	539	0.523	0.500	133	0.353	0.480
	Efficient use of inorganic fertilizers	672	0.643	0.480	539	0.685	0.465	133	0.474	0.501
Livestock Management practices	Use of plastic silos	672	0.109	0.311	539	0.122	0.328	133	0.0526	0.224
	Use of Muskan milk containers	672	0.138	0.346	539	0.152	0.359	133	0.0827	0.276
	Diversification of animal breeds	672	0.149	0.356	539	0.150	0.358	133	0.143	0.351
	Improved livestock breeds	672	0.263	0.440	539	0.258	0.438	133	0.195	0.398
	Fodder banks	672	0.185	0.388	539	0.217	0.413	133	0.0526	0.224

An analysis by sex of household heads also revealed that males predominantly adopted most crop management practices except for change of planting dates and intercropping. Females also tend to dominate land management practices like use of terraces and use of live fences. Farm risk reduction, soil and water conservation as well as livestock management practices were also mostly dominated by men. This could be due to the fact that although women are the ones who engage in farming, the farming decisions and CSA practices to be adopted are predominantly made by men.

In addition, an analysis of the summary statistics based on agro-ecological zones revealed that in all agro-ecological zones the predominant CSA practices were crop management practices (see Table A7 and A8 in the annex). We also found that in all zones, the traditional practices such as intercropping and application of organic manure still reined as shown in Table A7 and A8 in the annex.

Descriptive statistics

It is important to note that adoption of CSA practices is voluntary and maybe based on self-selection. In addition, Table 6 revealed that households adopting CSA practices have systematically different characteristics from non-adopters of CSA practices. This could be the case since households may adopt CSA practices based on anticipated benefits, level of knowledge on CSA and whether household has received training on CSA among other factors.

Table 6. Descriptive statistics.

	CSA adopters		CSA non-adopters		Mean difference	
Variable	Mean	s.e.	Mean	s.e.	Mean	s.e.
Dependent variables						
Total value of livestock holding	1593751***	(339549)	1855097***	(879455)	261346	(1221560)
Total Value of Agric yield	133679	(49754)	43984***	(9468)	-89695**	(38781)
Per capita monthly expenditure	5446.84***	(381.17)	3749.45***	(187.15)	-2097.39***	(378.55)
Explanatory variables						
Age of HH head (years)	49.74***	(0.8590)	48.6422***	(0.7307)	-1.1036	(1.1773)
HH sex	0.8475***	(0.0234)	0.7775***	(0.0199)	-0.0699**	(0.0321)
1 if HH head is married	0.8814***	(0.0210)	0.7408***	(0.0210)	-0.1405***	(0.0325)
HH head years of education	11.1102***	(0.3011)	8.3349***	(0.2573)	-2.7753***	(0.4140)
HH number of children	2.3220***	(0.1341)	2.9587***	(0.1157)	0.6367***	(0.1857)
HH size	5.7712***	(0.1533)	6.0436***	(0.1176)	0.2724	(0.1956)
1 if member of local group	0.6864***	(0.0303)	0.6376***	(0.0230)	-0.0488	(0.0384)
1 if HH head employed	0.8941***	(0.2008)	0.5734***	(0.2371)	-0.3207***	(0.0355)
1 if HH head own smartphone	0.6822***	(0.4495)	0.4495***	(0.0239)	0.2327***	(0.0394)
1 if HH head has access to loan	0.7966***	(0.0263)	0.4725***	(0.0239)	-0.3241***	(0.0378)
Amount of credit received	74144***	(11013)	59573***	(9098)	-14571	(14785)
1 if HH has crop insurance	0.0720***	(0.0169)	0.0298***	(0.0082)	-0.0422**	(0.0166)
1 if HH has livestock insurance	0.1102***	(0.0204)	0.1376***	(0.0059)	-0.0960***	(0.0168)
1 if HH has woodlot	0.3771***	(0.0316)	0.1697***	(0.0180)	-0.2074***	(0.0338)
1 if HH received Agric Information	0.7331***	(0.0289)	0.4794***	(0.0240)	-0.2537***	(0.0389)
1 if HH received weather information	0.8093***	(0.0256)	0.5092***	(0.0240))	-0.3001***	(0.0376)

1 if HH was visited by agrix extension	0.2585***	(0.0286)	0.0688***	(0.0121)	-0.1897***	(0.0267)
1 if HH received input subsidy	0.2119***	(0.0267)	0.1353***	(0.0164)	-0.0765**	(0.0297)
1 if HH receive insurance subsidy	0.0720***	(0.0169)	0.0619***	(0.0115)	-0.0101	(0.2001)
1 if county contact on CSA	0.2669***	(0.0289)	0.2064***	(0.0194)	-0.0605*	(0.0339)
1 if HH received market information	0.8475***	(0.0235)	0.4037***	(0.0235)	-0.4438	(0.0363)
1 if grew crops last season	0.9492***	(0.0143)	0.5849***	(0.0236)	--0.3642***	(0.0338)
HH land size (Acres)	4.1858***	(0.7209)	2.9683***	(0.3280)	-1.2175*	(0.6927)
1 if HH head is a native	0.7415***	(0.0286)	0.7775***	(0.0199)	0.0360	(0.0343)
1 if HH head heard of CSA	0.4661***	(0.0325)	0.3624***	(0.0230)	-0.1037**	(0.0394)
1 if HH trained on CSA	0.1186***	(0.0211)	0.0986***	(0.0143)	-0.0200	(0.0249)
Distance to forest(km)	23.8263***	(1.4749)	23.9914***	(1.3927)	0.1651	(2.1822)
Distance to school (km)	22.3289***	(6.6664)	2.6040***	(0.1188)	-19.7249	(4.9042)
Distance to livestock markt (km)	4.8284***	(0.2896)	8.1951***	(0.3243)	3.3667***	(0.4896)
Distance to crop market (km)	4.1886***	(0.2194)	4.7362***	(0.2762)	0.5477	(0.4088)
Distance to tarmac road (km)	10.5552***	(1.4815)	7.0935***	(0.7002)	-3.4617**	(1.4467)
Distance to agrovet (km)	4.6712***	(0.5677)	10.0103***	(0.6745)	5.3391***	(1.0076)

Unobserved factors may also influence household adoption of CSA practices as well as the outcome variables (total value of livestock holding, total value of agricultural yield and per capita monthly expenditure). Ignoring these factors may lead to biased and inconsistent estimates of the impact of adoption of CSA practices. Overall, the significant mean differences for some covariates (see Table 7) suggest that observed outcomes for non-adopters of CSA may not provide good counterfactual for adopters of CSA. In addition, since adoption of CSA practices was not purely random, we extended the analysis further by estimating a PSM model to handle self-selection issues and Lewbel's heteroscedasticity based instrumental variable model that uses internally generated instruments to address the endogeneity concerns.

Propensity score matching estimation results

The estimation of PSM requires that the two key assumptions of unconfoundedness and overlap are met. Performing an initial balance test is therefore critical. Table 7 suggests significant differences between adopters and non-adopters of CSA practices. To match and balance the data, we first estimated a probit model regression on adopters and non-adopters of CSA practices. It is important to note that there is no consensus within literature on whether to include the significant variables or all prior variables as predictors of propensity scores (Rubin 1979; Austin et al. 2007). However, for this study, we identified appropriate covariates from the household level data considering economic theory and condition that the covariates should influence household decisions to adopt CSA and outcome variables simultaneously but also be unaffected by the treatment (Heckman et al. 1998). Table 7 presents the PSM estimates of CSA adoption.

Table 7. Propensity Score Estimates of CSA adoption/Determinants of CSA adoption.

VARIABLES	(1) Coefficients	(2) Marginal Effects
Age of HH head (years)	0.0607** (0.0249)	0.0193** (0.00782)
Age^2 of HH head	-0.000605** (0.000243)	-0.000192** (7.64e-05)
HH size	-0.0222 (0.0250)	-0.00704 (0.00792)
1 if HH sex is male	-0.683*** (0.198)	-0.217*** (0.0611)

1 if HH head is married	0.897*** (0.197)	0.284*** (0.0595)
1 if HH head own smartphone	0.417*** (0.119)	0.132*** (0.0365)
1 if HH received input subsidy	0.266* (0.150)	0.0843* (0.0472)
1 if HH head is a native	0.0221 (0.134)	0.00702 (0.0427)
1 if HH crop farmer	1.268*** (0.218)	0.402*** (0.0646)
Number of Agric Extension visit	0.0131 (0.00984)	0.00417 (0.00311)
1 if county contact on CSA	0.133 (0.149)	0.0422 (0.0473)
1 if HH trained on CSA	-0.0819 (0.193)	-0.0260 (0.0613)
1 if HH head heard of CSA	-0.0953 (0.149)	-0.0302 (0.0473)
1 if HH experienced insuff rain	-0.114 (0.130)	-0.0361 (0.0411)
Constant	-3.179*** (0.646)	
Observations	672	672

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 8 shows that adoption of CSA increases with age at a decreasing rate and that as one gets older the probability of adopting CSA practices reduces. This is because as farmers get older, they have less energy to engage in physical activities. Male headed households are also less likely to adopt CSA practices supporting findings by Wekesa et al. (2018). This is mainly because in rural areas where the study was conducted farming is mostly left to women as men venture into other activities. The married are also more likely to adopt CSA practices. This could be due to division of labour among households whereas the husband ventures into off-farm jobs and the wife ventures into farming hence ensuring food security for the household from both angles. Households that own smart phones also tend to be more likely to adopt CSA practices. This could be due to possibility of googling CSA practices or even accessing information on CSA through the mobile phones. In addition, supporting works of Caron et al. (2018), the study revealed that where counties give input subsidy to

farmers the likelihood of adopting CSA practices becomes higher. It was also more evident that crop farmers are more likely to adopt CSA practices similar to findings by McCord et al. (2015). This also explains the predominance of adoption of CSA practices inclined to crop management/farming.

Factors influencing choice of CSA practices

The analysis was extended further by assessing factors influencing the choice of CSA practices among smallholder farmers. The CSA practices in Table 5 were condensed into the five groupings. The PCA was preferred instead of an additive index since it produces a more effective measure (Darnell 1994). The Kaiser-Meyer Olkin (KMO) measure of sampling adequacy revealed that crop management practices, land management practices, farm risk diversification, soil and water conservation, and livestock management practices had an overall KMO measure of 0.72, 0.58, 0.50, 0.59 and 0.56 respectively allowing use of PCA. The PCA results revealed that the first two components had eigen values greater than one dominates in terms of eigen values and proportion of variance. The first component also makes more economic sense since none of the coefficients was negative. The first component vector also contains positive weights for all the CSA practices under each grouping, an evidence of aggregate variation as a result of variation in adoption levels by households (Fujiie et al. 2005). The study therefore classified households based on PC Scores with PC scores greater than zero as adopters of CSA and those with less than zero as non-adopters. We then estimated a probit model to identify the factors influencing adoption of the CSA practices. The results are presented in Table 8.

Table 8. Factors influencing choice of CSA practices

VARIABLES	(1) CropManagement	(2) LandManagement	(3) FarmRisk	(4) SoilConserv	(5) LiveManagement
Age of HH head (years)	0.0866***	0.0193	-0.0291	0.0734***	0.00860
	(0.0277)	(0.0243)	(0.0255)	(0.0260)	(0.0273)
Age2 of HH head	-0.000806***	-0.000161	0.000471*	-0.000774***	-0.000115
	(0.000271)	(0.000243)	(0.000258)	(0.000257)	(0.000273)
1 if HH sex is male	-0.636***	-0.481**	0.743***	0.106	-0.480**
	(0.221)	(0.221)	(0.214)	(0.212)	(0.214)

1 if HH head is married	1.372*** (0.225)	1.857*** (0.228)	-0.502** (0.219)	-0.486** (0.203)	0.723*** (0.210)
HH head years of education	-0.0265* (0.0147)	-0.00115 (0.0137)	0.0386** (0.0157)	0.0370** (0.0158)	0.0549*** (0.0169)
1 if HH head own smartphone	-0.240* (0.145)	0.361*** (0.138)	0.698*** (0.154)	-0.708*** (0.153)	-0.133 (0.151)
HH number of children	0.0286 (0.0332)	-0.0615** (0.0306)	-0.0787** (0.0321)	-0.0535* (0.0322)	-0.175*** (0.0419)
1 if HH head is a native	-0.0772 (0.156)	0.250* (0.151)	-0.0719 (0.161)	0.116 (0.149)	0.642*** (0.164)
1 if county contact on CSA	0.933*** (0.185)	0.781*** (0.171)	0.688*** (0.188)	0.360** (0.168)	-0.409** (0.175)
1 if HH trained on CSA	-0.410 (0.274)	0.684*** (0.229)	0.745** (0.319)	0.632** (0.281)	-1.110*** (0.297)
1 if HH received input subsidy	0.512*** (0.178)	-0.836*** (0.173)	-0.683*** (0.180)	0.155 (0.171)	0.784*** (0.168)
1 if HH experienced hailstorm	0.441*** (0.169)	-0.260 (0.161)	0.494*** (0.164)	0.904*** (0.167)	0.570*** (0.184)
1 if HH was visited by extension officer	0.447** (0.207)	0.538*** (0.207)	0.273 (0.229)	0.718*** (0.198)	0.288 (0.208)
1 if HH head heard of CSA	-0.0771 (0.177)	-1.206*** (0.177)	-0.146 (0.189)	-0.496*** (0.168)	-0.217 (0.170)
1 if HH experienced insuff rain	0.0129 (0.164)	-0.346** (0.152)	0.456** (0.178)	-0.296* (0.162)	-0.137 (0.160)
1 if HH crop farmer	0.774***	1.301***	1.140***	0.704***	0.251

	(0.240)	(0.211)	(0.225)	(0.246)	(0.256)
1 if HH head has access to loan	1.280***	0.266	0.564***	1.054***	0.177
	(0.169)	(0.162)	(0.169)	(0.168)	(0.177)
1 if HH member of local group	-0.554***	0.166	0.177	-0.400***	-0.323**
	(0.140)	(0.132)	(0.136)	(0.147)	(0.143)
HH Monthly Income	9.23e-06***	-7.53e-06***	-8.96e-06***	3.71e-06*	1.05e-05***
	(2.69e-06)	(2.14e-06)	(2.04e-06)	(2.10e-06)	(2.85e-06)
1 if County has KCSAP	-0.210*	-0.264**	-0.00693	-0.137	-0.259**
	(0.126)	(0.119)	(0.126)	(0.124)	(0.129)
Distance to crop market (km)	0.0383***	-0.0359***	-0.00203	0.0707***	-0.0104
	(0.0123)	(0.0137)	(0.0129)	(0.0127)	(0.0167)
Constant	-4.337***	-2.066***	-1.700***	-3.063***	-1.891***
	(0.729)	(0.627)	(0.632)	(0.684)	(0.702)
Observations	672	672	672	672	672

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The results show that the adoption of crop management and soil conservation practices increases with age at a deceasing rate and that as people get older, they stop adopting crop management and soil conservation practices. This is due to lack of physical energy. Male headed households are also less likely to adopt crop management, land management, farm risk reduction and livestock management practices. The married are also more likely to adopt crop and land management practices but less likely to adopt farm risk reduction, soil conservation and livestock management practices.

The educated are also more likely to adopt farm risk reduction, soil conservation and livestock management practices. This is because they are more informed and have access to information on CSA. Those who own smart phones are more likely to adopt land management and farm risk reduction practices but less likely to adopt soil conservation and

crop management practices. Natives15 are also more likely to adopt land management and livestock management practices. The results revealed that households that received communication from county government on CSA were more likely to adopt crop management, land management farm risk reduction and soil conservation practices. This implies that county government communication to households is very effective in promoting CSA. Households that have received training on CSA are more likely to adopt land management, farm risk reduction and soil and water conservation practices but less likely to adopt livestock management practices. This could be due to costs associated with livestock management practices hence a deterrence for most households.

Households that receive input subsidies were also found to be more likely to adopt crop management and livestock management but less likely to adopt land management and farm risk reduction practices. The subsidies could be the incentive for adoption of crop management and livestock management practices. In terms of climatic variables, the study revealed that households that had experienced hailstorms in the past were more likely to adopt crop management, farm risk reduction, soil and water conservation and livestock management practices. In addition, the study also found that those households that had been visited by agriculture extension officers were more likely to adopt crop management, land management and soil and water conservation practices.

Households that had access to loans were more likely to adopt crop management, farm risk reduction and soil and water conservation practices. Crop farmers are also more likely to adopt crop management, land management, farm risk reduction and soil and water conservation practices. Income was also found to be a critical factor influencing uptake of CSA technologies. The study revealed that households with higher income were more likely to adopt crop management, livestock management and soil and water conservation practices but less likely to adopt land management and farm risk reduction practices.

Distance to the nearest crop market was found to be a critical factor as the study revealed that an increase in distance increases the likelihood of adoption of crop management

[15] A native is someone who was born in a given area and the great grand parents have also been born in the same area.

practices but reduces likelihood of adopting land management, farm risk reduction and soil and water conservation practices. The presence of the KCSAP project in a county was also found to have negative influence on uptake of crop management and land management practices. This implies that the promotion of CSA practices should take into consideration such factors.

Performance of matching estimators

The study considered a range of matches namely the nearest neighbour matching, radius matching and kernel matching. However, it is important to note that the choice of matching algorithm often involves a trade-off between bias and efficiency. We therefore selected matches that resulted in highest number of balanced covariates and large sample size within the common support as presented in Table 9. The kernel density showing the common support before and after matching is presented in Figure 1 in the annex. The figure depicts significant overlap after matching. A summary of the quality and performance of matching estimates is presented in Table 9.

The columns of interest are labelled (1), (6), (11), (16) and (2), (7), (12), (17). The study used fourteen explanatory variables to construct the propensity scores. A balance test of twelve and thirteen variables in columns (1), (6), (11) and (16) suggest an almost complete balance in matching. The pseudo R squared in column (2), (7), (12) and 17) just presents the explanatory power of the re-estimated propensity score model after matching. In the literature, a number of methods have been suggested for gauging performance of matching estimators. Some of these include checking if after matching the significant mean difference across covariates persists or re-estimating the probit regression using the matched sample (Sianesi 2004). The likelihood ration test of joint significant should also be rejected before matching but not after matching. In addition, after matching, there should not be any significant systematic differences between covariates hence the pseudo R squared should be low (Caliendo and Kopeinig 2008).

A critical look at the pseudo R squared reveals that the Kernel matches resulted in relatively lower pseudo R squared and high balanced covariates compared to other matches. The radius and nearest neighbour matches also have low balanced covariates with relatively

fewer matches and high pseudo R squared. This implies that estimates from the Kernel matches could be more superior to estimates from other matches.

Table 9. Performance of matching estimators.

Matching Estimator	PC Monthly Expenditure					Total value of livestock holding					Total value of agricultural yield				
	(1) Bal test*	(2) Ps R2	(3) LR Chi2	(4) P>Chi2	(5) Matched n	(6) Bal test*	(7) Ps R2	(8) LR Chi2	(9) P>Chi2	(10) Matched n	(11) Bal test*	(12) Ps R2	(13) LR Chi2	(14) P>Chi2	(15) Matched n
NN (2)	7	0.188	107.89	0.000	643	7	0.188	107.89	0.000	643	6	0.188	107.89	0.000	643
NN (3)	6	0.192	110.25	0.000	643	6	0.192	110.25	0.000	643	6	0.192	110.25	0.000	643
NN (4)	7	0.193	110.75	0.000	643	6	0.193	110.75	0.000	643	6	0.193	110.75	0.000	643
NN (5)	7	0.189	108.74	0.000	643	6	0.189	108.74	0.000	643	6	0.189	108.74	0.000	643
Radius	11	0.158	90.61	0.000	643	10	0.158	90.61	0.000	643	10	0.158	90.61	0.000	643
Radius	8	0.178	67.58	0.000	573	8	0.178	67.58	0.000	573	8	0.178	67.58	0.000	573
Radius	6	0.165	83.70	0.000	619	6	0.165	83.70	0.000	619	6	0.165	83.70	0.000	619
Kernel	13	0.014	9.12	0.823	672	13	0.014	9.12	0.823	672	13	0.014	9.12	0.823	672
Kernel	10	0.053	34.63	0.002	672	9	0.053	34.63	0.002	672	9	0.053	34.63	0.002	672
Kernel	11	0.025	16.66	0.275	672	11	0.025	16.66	0.275	672	11	0.025	16.66	0.275	672

* covariates with insignificant mean difference between beneficiaries and non-beneficiaries after matching

Matching based treatment effects on CSA adopters

The estimated ATT are presented in Table 11 for all the matching algorithms, including the ones that did not perform better. The table presents the estimated ATT for per capita household expenditure as a measure of welfare, total value of livestock holding and total value of agricultural holdings. The ATT were estimated using psmatch2 (Leuven and Sianesi 2003). The columns of interest are labelled ATT and t-stat.

Table 10. Matching based treatment effects.

Matching Estimator	Total value of Livestock Holding			Total value of agricultural yield			Per capita Monthly Household Expenditure		
	ATT	S.Dev.	t-stat	ATT	S.Dev.	t-stat	ATT	S.Dev.	t-stat
NN (2)	877170	510511	1.72*	105024	57156	1.84*	1126.24	692.52	1.63
NN (3)	947074	454780	2.08**	106796	56978	1.87*	892.52	650.10	1.37
NN (4)	959145	432546	2.22**	104482	67072	1.56	838.63	621.50	1.35
NN (5)	981960	420179	2.34**	106607	64525	1.65**	876.73	599.30	1.46
Radius (0.01)	834780	433085	1.93*	91466	59685	1.53	1260.85	547.42	2.30**
Radius (0.0025)	1075724	528555	2.04**	129041	93262	1.38	1858.97	779.54	2.38**
Kernel Bandwidth (0.1)	670498	1123768	0.60	79450	51073	1.56	857.59	444.14	1.93*
Kernel Bandwidth (0.0025)	1098137	2040035	0.54	96252	54264	1.77*	291.50	573.19	0.51
Kernel Bandwidth (0.005)	1032443	1621020	0.64	88576	52600	1.68*	487.30	508.99	0.96

*** p<0.01, ** p<0.05, * p<0.1

The results revealed that adoption of CSA has significant positive impacts (both economically and statistically) on total value of agricultural yield, total value of livestock holding and on household welfare as measured by per capita household expenditure. Specifically, the results revealed that CSA adoption: increases household welfare by between Ksh 444 (USD 4.44) and Ksh 779 (USD 7.79); increases total value of livestock holding by between Ksh 420,179 (USD 4201.79) and Ksh 528,555 (USD 5285.55); and increases value of agricultural yield by between Ksh 88,576 (USD 885.76) and Ksh 106,796 (USD 1067.96). The results show

that most communities either put in the returns from farming into savings through purchase of livestock or storing agricultural produce. In addition, through sale of agricultural produce most farmers are able to meet their daily livelihoods through purchase of basic requirements and also payment of school fees for their children as revealed during the FGDs.

Since we included even insignificant covariates even after matching, we assessed the robustness of our PSM estimates by running a matched regression with all controls. The results showed that the adoption of CSA still had significant impact on per capita monthly expenditure, value of livestock holding and value of agricultural produce.

Since matching is based on the uncounfoundedness assumption which is not testable, we conducted a sensitivity analysis of the matching estimates to assess the robustness of our estimates.

Sensitivity analysis of the matching estimates

PSM is based on the assumption of unconfoundedness or the conditional independence assumption, i.e., that the research should be able to observe all variables simultaneously influencing adoption of CSA and the outcome variable. Failure to satisfy this assumption would yield biased estimates due to hidden bias (Rosenbaum 2002). However, estimation of the extent of selection bias is quite complex especially due to the fact that we used non-experimental data. Using Rosenbaum's (2005) bounding approach to test for robustness of the matching estimates to unobserved variables, we examined the matching based treatment effects estimates with respect to potential deviations from conditional independence. The results of the sensitivity analysis are presented in Table 11.

Table 11. Sensitivity analysis of matching estimates.

	PCMonthly Exp		Value of Livestock Holding		Value of Agricultural yield	
Gamma	sig+	sig-	sig+	sig-	sig+	sig-
1	0.00937	0.00937	1.8e-07	1.8e-07	0. 849398	0. 849398
1.100	0.0393	0.00160	3.5e-06	6.5e-09	0. 948427	0. 670129
1.200	0.111	0.000233	0.000036	2.1e-10	0. 985261	0. 459884
1.300	0.233	3.00e-05	0.000243	6.4e-12	0. 996363	0. 274741
1.400	0.392	3.50e-06	0.001149	1.8e-13	0. 999204	0.14451
1.500	0.559	3.80e-07	0.004102	5.1e-15	0. 999842	0. 067923
1.600	0.706	3.80e-08	0.011681	1.1e-16	0. 999971	0. 028956

1.700	0.820	3.70e-09	0.027662	0	0. 999995	0. 011348
1.800	0.897	3.40e-10	0.056267	0	0. 999999	0. 004136
1.900	0.945	0	0.100891	0	1	0. 001416
2	0.972	0	0.162836	0	1	0. 000459

* gamma log odds of differential assignment due to unobserved factors

sig+ upper bound significance level

sig- lower bound significance level

The first column contains the log odds of differential assignment due to unobserved heterogeneity, and the second columns to seventh column contains the upper and lower bound significance levels respectively for the key outcome variables namely per capita monthly expenditure and value of agricultural yield and livestock holding. The second to seventh columns examine the match-based treatment effect for each measure of unobservable potential selection bias. The lower bounds are of no interest since they hold under the assumption that the true ATT is underestimated but our ATT estimates are positive (Becker and Caliendo 2007).

For instance, the sensitivity analysis results in Table 11 revealed that at $\Gamma = 1$ and $\Gamma = 1.1$ the results will be insignificant at 5% and 10% respectively. This suggests that unobserved covariates could cause the odds ratio of treatment assignment to differ between participants and non-participants once we reach a specific Γ level. We can therefore infer that the PSM estimates depict some level of sensitivity. However, Becker and Caliendo (2007) posit that the critical Γ=1.2 is not an indication that unobserved heterogeneity exists and that there is no effect of treatment on the outcome variable. The unconfoundedness cannot therefore be justified using this test hence we cannot conclude that the CIA holds or not. The results just indicate that if any unobserved variable caused the odds ratio of treatment assignment to differ between treatment and comparison groups say $\Gamma = 2$ then the confidence interval for the treatment effect would include zero (Becker and Caliendo 2007).

In addition, it is important to note that adoption of CSA is potentially endogenous to per capita monthly expenditure, total value of agricultural yield and livestock holding. This is because adoption of CSA is expected to increase agriculture and livestock production and by extension income and hence increased expenditure. Since adoption of CSA could be influenced by household income as most rich households tend to adopt CSA, an increase in

income from agricultural and livestock production would lead to increased uptake of CSA too, hence reverse causality.

Lewbel's Heteroscedasticity based instrumental variable results

The study therefore extended the analysis by employing other extended regression models, specifically the instrumental variable regression. Cameron and Trivedi (2005) highlight the difficulty of finding suitable instruments that satisfies the two conditions of validity and that the instrument must be highly correlated with adoption of CSA technologies but uncorrelated with the error term in the regression model. To examine the impact of CSA adoption on the three outcome variables, we first tested for endogeneity of CSA adoption. We used the control function approach to test for endogeneity. This approach is executed in two stages. The first stage, the endogenous variable (CSAPractice) is regressed on the instrumental variable ResidSta (a dummy variable whether one is a native of a village or not)[16] and other explanatory variables and predicted residuals saved.[17] In the second step, the outcome variables are regressed on the endogenous variables with other explanatory variables and the residuals (Wooldridge 2010).

Using this test, the null hypothesis of exogeneity is rejected for per capita expenditure with a p-value of 0.00 but is not rejected for total value of agricultural yield and livestock holding with a p-value of 0.149 and 0.124 respectively. We therefore proceeded to employ Lewbel's Heteroscedasticity based instrumental variable approach (Lewbel 2012; Baum and Schaffer 2020) that uses internally generated instruments to test and address the potential endogeneity of adoption of CSA on the outcome variables. This approach rules out the problem of identification of instruments that meet the strict conditions. The method estimates an instrumental variable regression model providing options to generate instruments and allows identification of structural parameters in regression models with

[16] The choice of the instrumental variable was based on the fact that natives could easily adopt CSA practices to conserve their soil and maximize output since they have nowhere else to go. Hence influencing agricultural yield and per capita expenditure but cannot influence the outcomes directly except through the adoption of CSA.

[17] We computed the proportion of the predicted probabilities outside the unit interval. Finding only 6.4% fell outside the unit interval we chose the LPM over the probit or logit model since the LPM would still produce unbiased and consistent. estimates (Horrace and Oaxaca 2006). The F value for the LPM model was also found to be 11.15 with a p value of 0.000 showing the significance of the LPM model

endogeneity or mismeasured regressors in the absence of traditional information on external instruments (Lewbel 2012).

According to Baum and Schaffer (2020), identification is achieved by having explanatory variables that are uncorrelated with the product of heteroskedastic errors which is a key feature of models where the correlations in the error term are due to unobserved common factor. This approach is therefore well applied when there are no external instruments or used to supplement weak external instruments to improve efficiency of the instrumental variable estimator (Lewbel 2012).

Table 12 presents the results of the Lewbel's heteroscedasticity based instrumental variable approach. We present results for all the outcome variables including those that were exogenous like total value of livestock holding and agricultural yield. We first tested whether the excluded instruments are correlated with the endogenous regressors (under-identification). Based on Kleibergen-Paarp rk LM statistic (see Table A1in the Annex), we reject the null hypothesis that the equations are under-identified at 1% level of significance. In the second step, we tested for weak identification since, if excluded instruments are weakly correlated with the endogenous regressors, then the instruments may yield poor estimates. Using the Craig-Donald Wald F statistic, we reject the null of weak identification as shown by the large F statistic for all the three outcomes. The Hansen J statistic was also used to test for over-identification under the null hypothesis that the instruments are valid (i.e., uncorrelated with the error term and the excluded instruments are correctly excluded from the estimated equation). Under this test, we reject the null hypothesis that the instruments are valid. These results show that the validity of over-identifying restrictions provides limited information on the ability of the instruments to identify parameters of interest. However, it is important to note that this is not a finite sample limitation of the test but just one of its intrinsic characteristics (Parente and Silva 2012). According to Parente and Silva (2012), the test checks the coherence of the instrument and not validity of the instruments. We can therefore still make inference based on the instrumental variable estimates. Although the test for endogeneity revealed that OLS provides better estimates for total agricultural yield and livestock holding, the impact is consistent throughout. The discussion of the results will be based on the IV estimates in Table 12.

Table 12. Lewbel's Heteroscedasticity Based Instrumental Variable Results

VARIABLES	(1) IVTotLivHold	(2) IVAgricyield	(3) IVPCMonthlyE xp
1 if HH adopts CSA (Treatment)	5.561e+06*** (1.900e+06)	219,305*** (62,603)	1,298*** (455.5)
Age of HH head (years)	-599,531** (243,856)	-8,709 (8,037)	-146.6** (58.48)
Age2 of HH head	5,252** (2,423)	66.46 (79.84)	1.397** (0.581)
1 if HH sex is male	5.436e+06*** (2.078e+06)	69,360 (68,475)	1,629*** (498.2)
1 if HH head is married	-8.679e+06*** (2.020e+06)	-10,088 (66,574)	208.6 (484.4)
1 if HH was visited by agrix ext	9.769e+06*** (2.010e+06)	-187,196*** (66,244)	-2,562*** (482.0)
1 if HH experienced hailstorm	-3.003e+06* (1.592e+06)	8,793 (52,460)	-2,486*** (381.7)
HH number of children	-706,914* (374,308)	12,980 (12,336)	-315.1*** (89.76)
HH size	778,225** (346,023)	-19,684* (11,404)	22.93 (82.98)
1 if HH head is a native	2.947e+06** (1.483e+06)	87,577* (48,863)	1,793*** (355.5)
1 if HH received input subsidy	2.274e+06 (1.635e+06)	2,256 (53,882)	-1,378*** (392.1)
1 if county has KCSAP	117,082 (1.152e+06)	-23,905 (37,978)	-542.7** (276.3)
HH head years of education	206,179 (135,156)	-15,634*** (4,454)	194.2*** (32.41)
1 if county contact on CSA	5.095e+06*** (1.539e+06)	-79,430 (50,727)	850.1** (369.1)
1 if HH member of local group	1.140e+06 (1.364e+06)	46,141 (44,940)	1,129*** (327.0)
1 if HH trained on CSA	-5.579e+06** (2.253e+06)	88,258 (74,264)	-251.1 (540.4)
1 if HH head has access to loan	-5.288e+06*** (1.577e+06)	-46,692 (51,981)	1,848*** (378.2)
1 if HH is a fish farmer	4.682e+06** (2.169e+06)	-82,494 (71,471)	985.3* (520.1)
1 if HH is livestock farmer	9.969e+06** (4.035e+06)	146,652 (132,972)	-507.6 (967.6)

1 if HH crop farmer	5.425e+06 (4.802e+06)	301,313* (158,247)	3,593*** (1,151)
1 if HH is mixed farmer	-1.239e+07** (5.040e+06)	-203,773 (166,104)	-2,046* (1,209)
1 if HH head employed	465,080 (1.629e+06)	-48,574 (53,699)	-358.7 (390.7)
1 if HH head own smartphone	-618,605 (1.363e+06)	121,420*** (44,929)	2,318*** (326.9)
Distance to livestock market (km)	62,012 (115,348)	3,607 (3,801)	-76.01*** (27.66)
HH land size (Acres)	22,496 (71,348)	3,540 (2,351)	-27.34 (17.11)
Constant	8.016e+06 (6.626e+06)	112,662 (218,375)	2,701* (1,589)
Observations R-squared	672 0.122	672 0.061	672 0.497

Conditioned on a set of covariates, the results show that adoption of CSA has a statistically and economically significant positive impact on per capita expenditure as a measure of household welfare and total value of agricultural yield and total value of livestock holding. These findings lend support to the works of other authors who found that adoption of CSA practices had positive effect on total agricultural yield, supporting findings by Kaumbutho and Kienzle (2007), Pretty (1999), Altieri (1999), Mendola (2007), Radeny et al. (2018), Asfaw et al. (2016), Wekesa et al. (2018) and Hine and Pretty (2008) who found different CSA practices to lead to increase in yields of cereals in Brazil and parts of Rift Valley and Western Kenya. The results therefore imply that adoption of more CSA practices increases agricultural crop productivity.

The results also show that total livestock holding and per capita expenditure decreases with age at an increasing rate. This could be due to the fact that at a younger age, people tend to be less engaged in agricultural activities, especially the youth, but as they age, they tend to venture more into agricultural practices. It was also evident from the field work that most farmers were mainly the aged, with an average age of about 50 years. Male headed households also experience increased value of livestock holding and per capita expenditure. This still reveals that there are still some gender disparities at community level. In addition,

livestock is often associated with males in the community. The males also tend to have more energy to engage in physical activities at the community level hence the more income to the household and by extension increased per capita expenditure. The study results also showed that households that had been visited by extension officers had higher value of livestock holding but lower per capita monthly expenditure. This could be due to the fact that with extension visits there is increased livestock production and reduced expenditure since extension services are provided for free by county officials. This implies with more extension services, then the adoption of CSA practices would be increased hence improved welfare of households.

As expected, the study revealed that natives were more active in agriculture as shown by the increase in total agricultural yield, livestock holding and per capita monthly expenditure. This could be due to the fact that natives believe they have no other home hence can only make good use of what they have. Households that received communication on CSA from counties also experienced increased per capita monthly expenditure and increased value of livestock holding. This shows that if the policy interventions at the national level can be cascaded down to the counties through a well-coordinated arrangement, then the impact could be higher than experienced currently. The results also revealed that the more years of education the higher the per capita expenditure but lower value of agricultural yield. This can be due to the fact that with more education there are more prospects or availability of better off-farm income hence higher per capita expenditure but low agricultural yield due to non-engagement in agriculture.

Although we expected positive spill-over effects as a result of presence of the KCSAP project in a county, the results depicted otherwise, showing the need for a better approach in implementing national government projects at the county level. As expected, livestock and fish farmers experienced increases in value of livestock holding. The study also revealed that an increase in distance to the nearest livestock market leads to reduction in per capita monthly expenditure. This shows that opportunity costs associated with distance matters a lot. This could also be due to the effect of engagement of brokers.

The results of the impact of specific categories of CSA practices are presented Tables A2-A6 in the annex. The results show that adoption of crop management practices had a positive

impact on value of agricultural yield and per capita monthly expenditure. Land management practices had a positive impact on value of agricultural crop yield but a negative impact on per capita monthly household expenditure. This could be due to redirection of household expenditure to the costly land management practices. However, farm risk reduction CSA practices had only a positive impact on total value of livestock holding. On the other hand, soil conservation practices had a positive impact on total value of livestock holding but unexpectedly had a negative impact on total value of agricultural crop yield. Livestock management practices also had an impact on per capita monthly household expenditure (see Table A2-A6 in the annex). The influence of other socioeconomic and demographic variables is similar to the discussion in the previous section.

Chapter five

Conclusion and recommendations

This study sought to assess the impact of CCAFS engagement at policy and household level and specifically assess to what extent CCAFS engagement contributed to the observed changes in terms of shaping policy and CSA coordination among others. From the key informant interviews at the national and county level, it was evident that most of climate change and climate smart agriculture practices have been mainstreamed into the national plans (Kenya Vision 2030 MTPs, the Big Four) and in most County Integrated Development Plans. This is also reflected in the indicator handbooks for tracking progress in implementation of the mentioned plans. The progress reports on implementation of the plans also revealed the same. For instance, the second “Big Four” report revealed that 488,793 farmers across 33 counties were provided insurance coverage against a target of 500,000 households in 37 counties.

The study found that CCAFS interventions have led to development of a range of policies aimed at promoting CSA. In effect, several counties have developed county policies on climate change, some have established climate change units and climate change funds, all aimed at promoting CSA. However, apart from the multi-stakeholder platforms, the coordination of CSA practices from the national government to the county government has been weak. This is despite CSA falling under food and nutrition security, one of the pillars of

the “Big Four”. This calls for a well-coordinated approach to ensure smooth flow of information from the national to the county level. From the KIIs and FGDs there is very little interaction from the national government through the counties to households, unlike before devolution when extension officers used to walk from farm to farm promoting government programmes like CSA at a community level. At the moment the two levels of governments work in silos which may compromise the realization of CCAFS objectives.

Despite the challenges, it is important to note that most of the policies in place at the national level and county levels would not have been in place without CCAFS interventions. It was noted that despite most counties being unaware of CCAFS, most tried to emulate what is happening at national level hence the establishment of climate change funds, climate change units and climate change policies in some of the counties. Further, the study revealed that the uptake of CSA practices is influenced by age and sex and marital status of household head. The uptake was also found to be influenced by ownership of smart phones and provision of input subsidies by county governments. Crop farming households were also found to be more likely to adopt CSA practices.

It was also found that rural households still continue to adopt the traditional CSA practices mainly: application of organic manure; intercropping; crop rotation changing planning dates; use of inorganic fertilizers; multi season crops; and use of live fences and terraces in all agro-ecological zones. The other approaches, such as irrigation, use of cover crops, crop and livestock insurance, use of muskan milk containers and plastic silos, is relatively low. The most predominant CSA practice in Kenya is therefore crop management practices followed by land management and soil and water conservation practices. In terms of gender, the study revealed that male headed households were more likely to adopt CSA practices compared to female headed households.

On the other hand, the choice of CSA practices among smallholder farmers was found to be influenced mainly by age, sex, marital status and education of household head. The choice of CSA practices is also influenced by smartphone ownership, residential status (i.e., whether native or immigrant), training on CSA, provision of input subsidy by counties, past experience of hailstorms/insufficient rains, visit by agricultural extension officers, knowledge on CSA and whether a household is a crop farmer. Other factors that were found to influence the choice

of CSA practices were household monthly income, household access to loans and distance to the nearest crop market. The choices of the type of CSA practices were also mainly dominated by males. This implies that in male dominated households most decisions on farming matters are made by men. Hence the need for increased sensitization of communities on the role of both genders in promoting CSA.

Overall, the adoption of the various CSA practices as well as the choice of CSA practices show that although there are some trickle-down effects of policy interventions to the household level, it is rather indirect and still low since most farmers have stuck to old traditional practices. The communication by counties to households for training on CSA were found not to have any influence on overall uptake of CSA practices but had a significant influence on the choice of some specific CSA practices adopted by households. Training on CSA also had positive influence on adoption of land management practices, farm risk reduction and soil and water conservation practices.

In terms of impact of adoption of CSA practices, the two empirical approaches employed in the study revealed that uptake of CSA by smallholder households had a statistically and economically significant impact on household welfare as measured by per capita household expenditure, total value of livestock holding and total value of agricultural yield. This was also supported with findings from the FGDs and KIIs. Some of the unintended impacts are the innovations like in Homa Bay where sweet potato farmers formed a marketing CBO. Although it is difficult to explicitly identify the mechanism of transmission of the impact, the study revealed that communication of CSA practices to households by county governments, sensitization of households through barazas (community events) and trainings had some effect. In addition, TV programmes like Shamba Shape Up have also been instrumental.

In conclusion, we find that CSA has the potential of improving welfare of smallholder farmers if they can adopt more CSA practices. It was found that there was no influence of county communication with households on uptake of CSA even though there was a positive impact on total livestock holding and per capita monthly expenditure. There is need for counties to establish an effective means of communication with households based on the heterogenous nature of communities in terms of level of education and access to information. Key lessons from the study are that increased sensitization of communities through barazas, TV and

radio adverts could increase uptake of CSA. A coordinated and integrated engagement between county and national governments can improve household welfare and food security through CSA. In addition, the study revealed that improvement of road infrastructure could enhance access to various market centres hence improving livelihoods of communities. The use of social groups and social media can easily promote CSA uptake since farmers tend to implement what they see happening with their fellow farmers.

In terms of policy recommendations, first, there is need for a well-coordinated and integrated approach to promotion of CSA practices from the national to county level. This is because the impact of policy interventions is still low especially from the national level to the grassroots. This calls for a change of approach, for instance bringing on board county representatives into the multi-stakeholder platform in an arrangement where the national government is also just a member. This is due to the fact that when most of these platforms are organized by national governments counties always feel they are being managed by the national government yet they are independent. The best entry point for such interventions would be the Council of Governors and incorporating political leadership through county assembly forums and the national assembly.

Although most of the CCAFS interventions at the national level are being felt in a way though little and indirectly, there is need for CCAFS to move a step further, for instance by dealing with counties directly for policy implementation since agriculture is a devolved function. This is because in developing countries of which Kenya is not an exception very well thought out policies are developed but implementation is often a problem. This situation is made worse by the disconnect between national and devolved governments which should be the best opportunities for trickling down of such interventions.

Policy makers with support from CCAFS could also consider county specific tailor-made interventions to promote CSA. Some counties also suggested that there is need for an act setting aside specific budget for agriculture in order to enhance uptake of CSA technologies to protect communities against the effects of climate change and vulnerability. To enhance uptake of agriculture and weather information, policy makers need to consider developing IEC products in local languages to be shared in local radio stations. To provide market opportunities, farmers need to be encouraged to engage in contract farming and joining

farmer cooperatives to increase access to market opportunities for their produce and avoid brokers.

There is also need for increased sensitization of farmers on the need to invest in CSA practices to cushion them against the risk of climate change and also increase adoption of modern CSA practices. The use of local radio stations is critical in promoting CSA as it has been effective in providing weather and agricultural information. Finally, the agricultural extension services need to be upscaled to increase reach of rural households by county governments.

References

Abadie A, Angrist J, Imbens G. 2002. Instrumental variables estimates of the effect of subsidized training on the quantiles of trainee earnings. *Econometrica* 70(1):91–117.

Africa Women Studies Centre and KNBS. 2013. Baseline Survey on Food security. Nairobi.

Altieri MA. 1999. Applying agroecology to enhance the productivity of peasant farming systems in Latin America. *Environment, Development and Sustainability* 1(3-4):197–217.

Arslan A, McCarthy N, Lipper L, Asfaw S, Cattaneo A. 2014. Adoption and intensity of adoption of conservation farming practices in Zambia. *Agriculture, ecosystems & environment* 187:72–86.

Asfaw S, Di Battista F, Lipper L. 2016. Agricultural technology adoption under climate change in the Sahel: Micro-evidence from Niger. *Journal of African Economies* 25(5):637–669.

Austin PC, Grootendorst P, Anderson GM. 2007. A comparison of the ability of different propensity score models to balance measured variables between treated and untreated subjects: A monte carlo study. *Statistics in medicine* 26(4):734–753.

Baum CF, Schaffer ME. 2020. Ivreg2h: Stata module to perform instrumental variables estimation using heteroskedasticity-based instruments. *Statistical Software Components*. Department of Economics, Boston College revised 26 June 2020.

Baumgärtner S, Quaas MF. 2010. Managing increasing environmental risks through agrobiodiversity and agrienvironmental policies. *Agricultural Economics* 41(5):483–496.

Becker SO, Caliendo M. 2007. Sensitivity analysis for average treatment effects. *The Stata Journal* 7(1):71–83.

Branca G, McCarthy N, Lipper L, Jolejole MC. 2011. Climate-smart agriculture: a synthesis of empirical evidence of food security and mitigation benefits from improved cropland management. *Mitigation of climate change in agriculture series* 3:1–42.

Caliendo M, Kopeinig S. 2008. Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys* 22(1):31–72.

Cameron AC, Trivedi PK. 2005. Micro-econometrics: Methods and Applications. Cambridge University Press, New York.

Campbell BM, Thornton P, Zougmoré R, van Asten P, Lipper L. 2014. Sustainable intensification: What is its role in climate smart agriculture? *Current Opinion in Environmental Sustainability* 8:39–43. SI: Sustainability governance and transformation.

Caron P, Dev M, Oluoch-Kosura W, Phat CD, Lele U, Sanchez P, Sibanda LM. 2018. Devising Effective Strategies and Policies for CSA: Insights from a Panel of Global Policy Experts. In

Lipper L, McCarthy N, Zilberman D, Asfaw S, Branca G. (eds.) Climate Smart Agriculture: Building Resilience to Climate Change, pp. 599–620. Springer International Publishing, Cham.

Chesterman S, Neely C. 2015. Evidence and policy implications of climate-smart agriculture in Kenya. CCAFS Working Paper no. 90. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

CIAT. 2015. Climate-smart tools for East Africa.

Cochran WG. 1963. Sampling Techniques, 2nd Ed., New York: John Wiley and Sons, Inc.

Collier P, Conway G, Venables T. 2008. Climate change and Africa. *Oxford Review of Economic Policy* 24(2):337–353.

Collins-Sowah PA. 2018. *Theoretical conception of climate-smart agriculture* (No. WP2018-02). Working Papers of Agricultural Policy.

Cutforth LB, Francis CA, Lynne GD, Mortensen DA, Eskridge KM. 2001. Factors affecting farmers' crop diversity decisions: An integrated approach. *American Journal of Alternative Agriculture* 16(4):168–176.

Darnell AC. 1994. A Dictionary of Econometrics. Technical report. Edward Elgar Publishing.

Di Falco S, Perrings C. 2003. Crop genetic diversity, productivity and stability of agroecosystems. A theoretical and empirical investigation. *Scottish Journal of Political Economy* 50(2):207–216.

FAO. 1996. Agro-Ecological Zoning: Guidelines. Natural Resources Management and Environment.

FAO. 2010. Climate smart agriculture: policies, practices and financing for food security. Rome: Adaptation and Mitigation.

FAO. 2013. *Climate-Smart Agriculture Sourcebook*. Food and Agriculture Organization of the United Nations (FAO).

Fujiie M, Hayami Y, Kikuchi M. 2005. The conditions of collective action for local commons management: the case of irrigation in the Philippines. *Agricultural Economics* 33(2):179–189.

GOK. 2010. National Climate Change Response Strategy. Ministry of Environment and Mineral Resources. Nairobi.

GOK. 2018. Third Medium Term Plan 2018–2022. Nairobi: Government of the Republic of Kenya.

Hansen JW, Mason SJ, Sun L, Tall A. 2011. Review of seasonal climate forecasting for agriculture in sub- Saharan Africa. *Experimental Agriculture* 47(2):205–240.

Heckman JJ, Ichimura H, Todd P. 1998. Matching as an econometric evaluation estimator. *The Review of Economic Studies* 65(2):261–294.

Heckman JJ, LaLonde RJ, Smith JA. 1999. The economics and econometrics of active labor market programs. Handbook of Labor Economics 3:1865–2097.

Hine R, Pretty J. 2008. Organic agriculture and food security in Africa. Geneva and New York, United Nations Conference on Trade and Development (UNCTAD) and United Nations Environment Programme (UNEP).

Horrace WC, Oaxaca RL. 2006. Results on the bias and inconsistency of ordinary least squares for the linear probability model. *Economics Letters* 90(3):321–327.

Kabubo-Mariara J, Kabara M. 2015. *Climate change and food security in Kenya. Environment for Development*. No. 15-05. Discussion Paper Series.

Kaumbutho P, Kienzle J. 2007. Conservation Agriculture as Practiced in Kenya: Two case studies. Roma, FAO.

Khandker SR, Koolwal GB, Samad HA. 2009. Handbook on impact evaluation: Quantitative methods and practices. World Bank Publications.

KNBS. 2019. 2019 Kenya Population and Housing Census. Vol. 1: Population by County and Sub-County. Govt Press.

KNBS. 2020. Economic Survey. Govt Press.

Leuven E, Sianesi B. 2003. Psmatch2 (version 3.0. 0): Stata module to perform full mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing.

Lewbel A. 2012. Using heteroscedasticity to identify and estimate mismeasured and endogenous regressor models. *Journal of Business & Economic Statistics* 30(1):67–80.

Lin BB. 2011. Resilience in agriculture through crop diversification: adaptive management for environmental change. *BioScience* 61(3)183–193.

Lipper L, Zilberman D. 2018. A Short History of the Evolution of the Climate Smart Agriculture Approach and Its Links to Climate Change and Sustainable Agriculture Debates. In: Lipper L, McCarthy N, Zilberman D, Asfaw S, Branca G. (eds.) *Climate Smart Agriculture: Building Resilience to Climate Change* pp.13–30. Springer International Publishing, Cham.

Lipper L, Thornton P, Campbell BM, Baedeker T, Braimoh A, Bwalya M, ... Hottle R. 2014. Climate-smart agriculture for food security. *Nature climate change* 4(12)1068–1072.

McCarthy N, Lipper L, Zilberman D. 2018. Economics of Climate Smart Agriculture: An Overview. In: Lipper L, McCarthy N, Zilberman D, Asfaw S, Branca G. (eds.) *Climate Smart Agriculture: Building Resilience to Climate Change*, pp.31–47. Springer International Publishing, Cham.

McCord PF, Cox M, Schmitt-Harsh M, Evans T. 2015. Crop diversification as a smallholder livelihood strategy within semi-arid agricultural systems near Mount Kenya. *Land Use Policy* 42:738–750.

Mendola M. 2007. Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh. *Food Policy* 32(3):372–393.

Michler JD, Baylis K, Arends-Kuenning M, Mazvimavi K. 2019. Conservation agriculture and climate resilience. *Journal of Environmental Economics and Management* 93:148–169.

Mukankusi CM, Nkalubo S, Katungi E, Awio B, Luyima G, Radeny M, Kinyangi J. 2015. Participatory Evaluation of Common Bean for Drought and Disease Resilience Traits in Uganda. CCAFS Working Paper no. 143. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.

Nikolaou G, Neocleous D, Christou A, Kitta E, Katsoulas N. 2020. Implementing sustainable irrigation in water-scarce regions under the impact of climate change. *Agronomy* 10(8): 1120.

Njeru E, Grey S, Kilawe E. 2016. *Eastern Africa climate-smart agriculture scoping study: Ethiopia, Kenya and Uganda.* Addis Ababa: Food and Agriculture Organization of the UN.

Notenbaert A, Karanja SN, Herrero M, Felisberto M, Moyo S. 2013. Derivation of a household-level vulnerability index for empirically testing measures of adaptive capacity and vulnerability. *Regional Environmental Change* 13(2):459–470.

Nyasimi M, Amwata D, Hove L, Kinyangi J, and Wamukoya G. (2014). Evidence of Impact: Climate-Smart Agriculture in Africa. CCAFS Working Paper no. 86. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.

Ochieng J, Kirimi L, Makau J. 2017. Adapting to climate variability and change in rural Kenya: farmer perceptions, strategies and climate trends. In: *Natural resources forum* 41(4):195–208. Oxford, UK: Blackwell Publishing Ltd.

Okumu B, Muchapondwa E. 2020. Welfare and forest cover impacts of incentive based conservation: Evidence from Kenyan community forest associations. *World Development* 129:104890.

Parente PM, Silva JS. 2012. A cautionary note on tests of overidentifying restrictions. *Economics Letters* 115(2):314–317.

Pretty J. 1999. Can Sustainable Agriculture Feed Africa? New Evidence on Progress, Processes and Impacts. *Environment, Development and Sustainability* 1:253–274.

Radeny M, Ogada MJ, Recha J, Kimeli P, Rao EJO, Solomon D. 2018. Uptake and Impact of Climate-Smart Agriculture Technologies and Innovations in East Africa. CCAFS Working

Paper no. 251. Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Rosenbaum PR. 2002. Observational Studies: Second Edition. Springer, New York.

Rosenbaum PR. 2005. Sensitivity analysis in observational studies. *Encyclopedia of Statistics in Behavioral Science* 4.

Roy AD. 1951. Some thoughts on the distribution of earnings. *Oxford Economic Papers* 3(2):135–146.

Rubin DB. 1973. Matching to remove bias in observational studies. *Biometrics* 159–183.

Rubin DB. 1979. Using multivariate matched sampling and regression adjustment to control bias in observational studies. *Journal of the American Statistical Association* 74(366a):318–328.

Schoonenboom J, Johnson RB. 2017. How to construct a mixed methods research design. *Kolner Zeitschrift fur Soziologie und Sozialpsychologie* 69(2):107–131.

Sere C, Steinfeld H. 1996. World livestock production systems: current status, issues and trends. FAO Animal Production and Health Paper 127. FAO, Rome, Italy.

Sianesi B. 2004. An evaluation of the Swedish system of active labor market programs in the 1990s. *Review of Economics and Statistics* 86(1):133–155.

Solomon D, Radeny M, Mungai C, Recha J, Schuetz T, Gadeberg M. 2018. CCAFS East Africa 2019–2021: Strategy for supporting agricultural transformation, food and nutrition security under climate change. Addis Ababa, Ethiopia: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Teklewold H, Mekonnen A. 2020. Weather at Different Growth Stages, Multiple Practices and Risk Exposures: Panel Data Evidence from Ethiopia. *Climate Change Economics* 11(2):2050009.

Thornton PK, Rosenstock T, Förch W, Lamanna C, Bell P, Henderson B, Herrero M. 2018. A Qualitative Evaluation of CSA Options in Mixed Crop-Livestock Systems in Developing Countries. In: Lipper L, McCarthy N, Zilberman D, Asfaw S, Branca G (eds). 2018. Climate Smart Agriculture Building Resilience to Climate Change. Natural Resource Management and Policy: Vol 52. Springer Cham. pp. 385–423.

Verhagen J, Vellinga T, Neijenhuis F, Jarvis T, Jackson L, Caron P, Torquebiau E, Lipper L, Fernandes E, Entsua-Mensah REM, Vermeulen S. 2014. Climate-Smart Agriculture: Scientists' perspectives. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen.

Wekesa BM., Ayuya OI, Lagat JK. 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. *Agriculture & Food Security* 7(1):80.

Westermann O, Thornton P, Förch W. 2015. Reaching more farmers – innovative approaches to scaling up climate smart agriculture. CCAFS Working Paper no. 135. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Wineman A, Mason NM, Ochieng J, Kirimi L. 2017. Weather extremes and household welfare in rural Kenya. *Food Security* 9(2):281–300.

Wooldridge JM. 2010. Econometric analysis of cross section and panel data. MIT Press.

Appendix

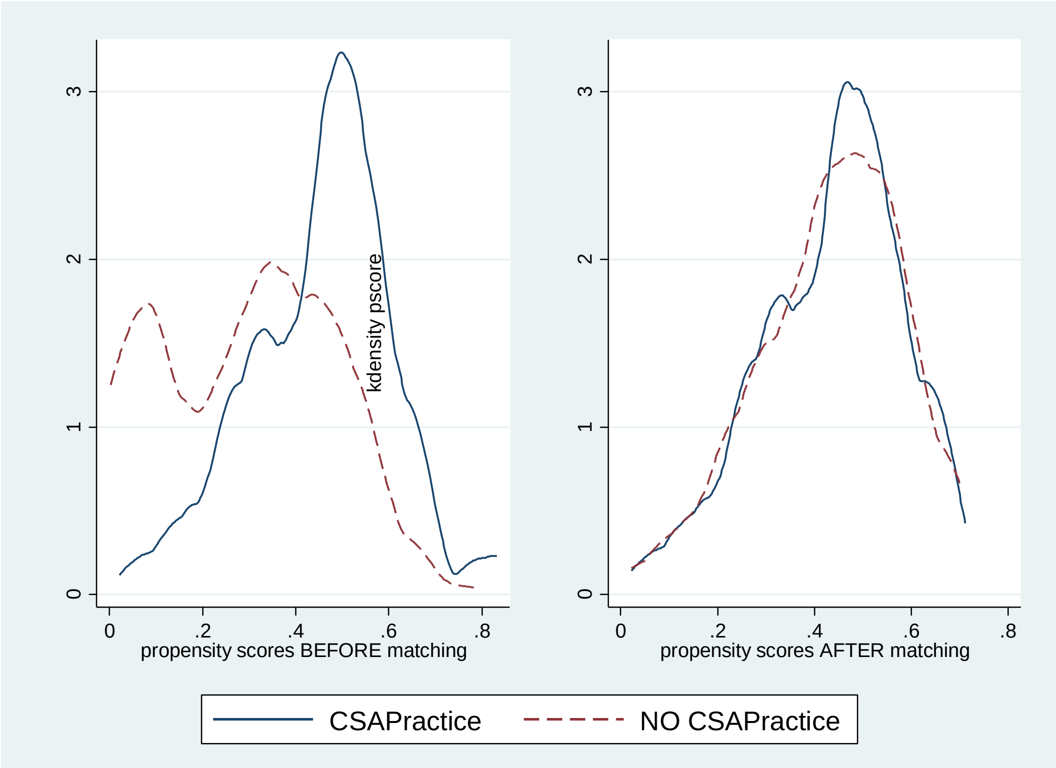

Figure 1. Propensity scores before and after matching.

Table A1. Performance statistics of IV models.

Test	Total Livestock Holding	Total Agricultural yield	Per capita Monthly expenditure
Under-identification test (Kleibergen-Paap rk LM statistic)	397.605	397.605	397.605
Chi-sq (24) p-val	0.000	0.000	0.000
Weak identification test (Cragg-Donald Wald F statistic)	37.614	37.614	37.614
Hansen J statistic (over-identification test of all instruments	59.407	130.780	171.385
Chi-sq (24) p-val	0.000	0.000	0.000

Table A2. Lewbel's IV estimates of impact of crop management practices.

VARIABLES	(1) IVTotLivHold	(2) IVAgricyield	(3) IVPCMonthlyExp
1 if HH adopts crop management practices	-309,549	148,454*	1,045*
	(2.361e+06)	(78,336)	(569.7)
Age of HH head (years)	-590,246**	-5,785	-119.5**
	(245,004)	(8,130)	(59.12)
Age2 of HH head	5,212**	40.97	1.220**
	(2,435)	(80.79)	(0.588)
1 if HH sex is male	3.202e+06	39,921	1,672***
	(1.992e+06)	(66,087)	(480.6)
1 if HH head is married	-6.170e+06***	-37,312	-28.24
	(2.035e+06)	(67,521)	(491.1)
1 if HH was visited by agric ext	1.101e+07***	-132,167**	-2,404***
	(1.935e+06)	(64,205)	(466.9)
1 if HH experienced hailstorm	-4.105e+06***	32,848	-2,023***
	(1.498e+06)	(49,713)	(361.5)
HH number of children	-498,349	17,213	-304.3***
	(365,916)	(12,142)	(88.30)
HH size	516,128	-21,242*	20.12
	(339,242)	(11,257)	(81.86)
1 if HH head is a native	2.264e+06	47,973	1,384***
	(1.406e+06)	(46,656)	(339.3)
1 if HH received input subsidy	2.473e+06	8,447	-1,414***
	(1.645e+06)	(54,578)	(396.9)
1 if county has KCSAP	-333,028	-29,204	-503.3*
	(1.146e+06)	(38,034)	(276.6)
HH head years of education	165,776	-8,887**	257.1***
	(119,314)	(3,959)	(28.79)
1 if county contact on CSA	5.142e+06***	-104,914**	519.0
	(1.610e+06)	(53,436)	(388.6)
1 if HH member of local group	-151,483	25,774	1,061***
	(1.333e+06)	(44,242)	(321.8)
1 if HH trained on CSA	-6.329e+06***	61,293	-409.9
	(2.244e+06)	(74,452)	(541.5)
1 if HH head has access to loan	-3.755e+06**	-48,988	2,090***
	(1.755e+06)	(58,248)	(423.6)
1 if HH is livestock farmer	2.606e+06	70,379	-1,517***
	(2.113e+06)	(70,102)	(509.8)
1 if HH head employed	1.835e+06	-6,730	71.61
	(1.556e+06)	(51,642)	(375.6)

1 if HH head own smartphone	-1.203e+06	117,566***	2,073***
	(1.334e+06)	(44,248)	(321.8)
Distance to livestock market (km)	68,129	1,311	-102.0***
	(111,771)	(3,709)	(26.97)
HH land size (Acres)	21,715	4,690**	-9.692
	(69,408)	(2,303)	(16.75)
Constant	1.377e+07**	193,128	3,657**
	(6.141e+06)	(203,770)	(1,482)
Observations	672	672	672
R-squared	0.121	0.048	0.490

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A3. Lewbel's IV estimates of impact of land management practices.

VARIABLES	(1) IVTotLivHold	(2) IVAgricyield	(3) IVPCMonthlyExp
1 if HH adopts Land Management practices	-395,698	131,596*	-3,781***
	(2.219e+06)	(73,542)	(558.4)
Age of HH head (years)	-589,917**	-4,835	-23.17
	(242,486)	(8,036)	(61.01)
Age2 of HH head	5,206**	33.69	0.350
	(2,418)	(80.14)	(0.608)
1 if HH sex is male	3.206e+06	35,829	1,462***
	(1.988e+06)	(65,890)	(500.3)
1 if HH head is married	-6.106e+06***	-46,109	1,678***
	(2.102e+06)	(69,660)	(528.9)
1 if HH was visited by agrix ext	1.107e+07***	-150,681**	-1,695***
	(1.974e+06)	(65,402)	(496.6)
1 if HH experienced hailstorm	-4.197e+06***	70,253	-2,329***
	(1.483e+06)	(49,159)	(373.3)
HH number of children	-508,497	20,496*	-409.3***
	(370,859)	(12,290)	(93.32)
HH size	525,558	-23,897**	152.5*
	(345,758)	(11,458)	(87.00)
1 if HH head is a native	2.264e+06	46,157	1,217***
	(1.405e+06)	(46,549)	(353.4)
1 if HH received input subsidy	2.362e+06	50,248	-2,057***
	(1.685e+06)	(55,843)	(424.0)
1 if county has KCSAP	-336,391	-30,416	-740.3**
	(1.145e+06)	(37,944)	(288.1)
HH head years of education	167,352	-9,159**	294.3***
	(120,029)	(3,978)	(30.20)

1 if county contact on CSA	5.119e+06***	-86,661*	1,212***
	(1.540e+06)	(51,033)	(387.5)
1 if HH member of local group	-75,755	-4,401	1,346***
	(1.329e+06)	(44,037)	(334.4)
1 if HH trained on CSA	-6.264e+06***	33,033	-345.9
	(2.223e+06)	(73,655)	(559.3)
1 if HH head has access to loan	-3.855e+06***	3,354	2,821***
	(1.457e+06)	(48,297)	(366.7)
1 if HH is livestock farmer	2.594e+06	71,458	-1,907***
	(2.115e+06)	(70,092)	(532.2)
1 if HH head employed	1.810e+06	5,248	137.3
	(1.546e+06)	(51,226)	(388.9)
1 if HH head own smartphone	-1.200e+06	114,929***	1,979***
	(1.332e+06)	(44,139)	(335.1)
Distance to livestock market (km)	63,051	2,951	-154.8***
	(115,798)	(3,837)	(29.14)
HH land size (Acres)	24,350	3,924*	25.10
	(71,728)	(2,377)	(18.05)
Constant	1.384e+07**	138,681	1,868
	(5.994e+06)	(198,651)	(1,508)
Observations	672	672	672
R-squared	0.121	0.050	0.446

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A4. Lewbel's IV estimates of impact of farm risk reduction practices.

VARIABLES	(1) IVTotLivHold	(2) IVAgricyield	(3) IVPCMonthlyExp
1 if HH adopts farm risk reduction practices	3.943e+06**	-39,282	257.7
	(1.913e+06)	(64,742)	(472.0)
Age of HH head (years)	-472,281**	-5,026	-121.5**
	(236,551)	(8,005)	(58.37)
Age2 of HH head	3,961*	36.08	1.165**
	(2,360)	(79.88)	(0.582)
1 if HH sex is male	3.079e+06	20,687	1,230**
	(2.020e+06)	(68,374)	(498.5)
1 if HH head is married	-7.104e+06***	31,899	507.8
	(1.947e+06)	(65,899)	(480.5)
1 if HH was visited by agrix ext	1.133e+07***	-129,407**	-2,211***
	(1.903e+06)	(64,404)	(469.6)
1 if HH experienced hailstorm	-3.283e+06**	30,262	-2,440***
	(1.585e+06)	(53,625)	(391.0)

HH number of children	-668,161*	17,964	-294.3***
	(365,932)	(12,384)	(90.29)
HH size	797,376**	-23,374**	12.27
	(340,475)	(11,523)	(84.01)
	2.177e+06	54,702	1,605***
1 if HH head is a native	(1.424e+06)	(48,206)	(351.5)
	3.002e+06*	14,874	-1,263***
1 if HH received input subsidy	(1.601e+06)	(54,199)	(395.2)
	-266,402	-39,981	-635.5**
1 if county has KCSAP	(1.119e+06)	(37,879)	(276.2)
	313,670**	-11,601***	218.6***
HH head years of education	(127,644)	(4,320)	(31.50)
	4.584e+06***	-71,623	825.9**
1 if county contact on CSA	(1.530e+06)	(51,795)	(377.6)
	230,928	8,015	909.2***
1 if HH member of local group	(1.295e+06)	(43,839)	(319.6)
	-7.316e+06***	52,157	-546.3
1 if HH trained on CSA	(2.198e+06)	(74,374)	(542.3)
	-4.645e+06***	14,443	2,120***
	(1.515e+06)	(51,273)	(373.8)
	4.601e+06**	-99,671	918.8*
1 if HH is a fish farmer	(2.122e+06)	(71,826)	(523.7)
	9.827e+06**	29,065	-921.9
1 if HH is livestock farmer	(4.017e+06)	(135,962)	(991.3)
	1.297e+06	106,303	2,520**
1 if HH crop farmer	(4.429e+06)	(149,873)	(1,093)
	-9.588e+06**	38,878	-941.9
1 if HH is mixed farmer	(4.759e+06)	(161,048)	(1,174)
	2.174e+06	-4,447	-38.94
1 if HH head employed	(1.556e+06)	(52,665)	(384.0)
	-1.437e+06	115,014**	2,215***
1 if HH head own smartphone	(1.354e+06)	(45,824)	(334.1)
	13,408	1,937	-86.51***
Distance to livestock market (km)	(111,919)	(3,788)	(27.62)
	70,023	4,214*	-20.33
	(70,359)	(2,381)	(17.36)
Constant	6.088e+06	158,774	2,667
	(6.589e+06)	(223,002)	(1,626)
Observations	672	672	672
R-squared	0.159	0.052	0.490

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A5. Lewbel's IV estimates of impact of soil and water conservation practices.

VARIABLES	(1) IVTotLivHold	(2) IVAgricyield	(3) IVPCMonthlyExp
1 if HH adopts soil conservation practices	8.215e+06*** (2.068e+06)	-119,709* (66,812)	469.5 (485.9)
Age of HH head (years)	-726,441*** (253,478)	-1,447 (8,191)	-136.2** (59.57)
Age2 of HH head	6,648*** (2,525)	-1.163 (81.58)	1.322** (0.593)
1 if HH sex is male	3.885e+06* (2.063e+06)	13,078 (66,664)	1,283*** (484.8)
1 if HH head is married	-6.030e+06*** (2.059e+06)	14,366 (66,548)	565.8 (484.0)
1 if HH was visited by agrix ext	9.772e+06*** (2.024e+06)	-107,085 (65,403)	-2,301*** (475.7)
1 if HH experienced hailstorm	-3.535e+06** (1.639e+06)	36,960 (52,955)	-2,449*** (385.1)
HH number of children	-555,051 (381,110)	16,638 (12,315)	-287.2*** (89.56)
HH size	778,399** (353,501)	-23,513** (11,423)	10.45 (83.07)
1 if HH head is a native	2.818e+06* (1.499e+06)	45,127 (48,446)	1,641*** (352.3)
1 if HH received input subsidy	2.433e+06 (1.667e+06) -84,745	21,661 (53,880) -42,717	-1,298*** (391.8) -625.2**
1 if county has KCSAP	(1.171e+06) 193,687	(37,849) -9,872**	(275.3) 211.7***
HH head years of education	(136,589) 4.271e+06***	(4,414) -64,457	(32.10) 812.7**
1 if county contact on CSA	(1.590e+06) 1.103e+06	(51,367) -4,902	(373.6) 958.7***
1 if HH member of local group	(1.374e+06) -7.193e+06***	(44,391) 53,384	(322.8) -533.9
1 if HH trained on CSA	(2.278e+06) -5.548e+06***	(73,595) 30,953	(535.2) 2,074***
1 if HH head has access to loan	(1.594e+06) 3.176e+06	(51,522) -80,205	(374.7) 835.0
1 if HH is a fish farmer	(2.233e+06) 1.275e+07***	(72,156) -23,898	(524.8) -773.7
1 if HH is livestock farmer	(4.246e+06)	(137,188)	(997.7)

	6.208e+06	31,730	2,795**
1 if HH crop farmer	(4.826e+06)	(155,947)	(1,134)
	-1.550e+07***	137,421	-1,258
1 if HH is mixed farmer	(5.253e+06)	(169,728)	(1,234)
	-90,349	26,376	-172.2
1 if HH head employed	(1.672e+06)	(54,013)	(392.8)
	37,243	95,942**	2,304***
1 if HH head own smartphone	(1.411e+06)	(45,594)	(331.6)
	-62,853	3,072	-90.83***
Distance to livestock market (km)	(118,766)	(3,838)	(27.91)
	89,041	3,824	-19.45
HH land size (Acres)	(73,339)	(2,370)	(17.23)
Constant	8.306e+06	137,852	2,814*
	(6.775e+06)	(218,918)	(1,592)
Observations	672	672	672
R-squared	0.081	0.055	0.495

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A6. Lewbel's IV estimates of impact of livestock management practices.

VARIABLES	(1) IVTotLivHold	(2) IVAgricyield	(3) IVPCMonthlyExp
1 if HH adopts livestock management practices	-1.180e+06	-83,582	2,146***
	(1.839e+06)	(61,022)	(439.3)
Age of HH head (years)	-594,628**	-2,129	-100.3*
	(238,614)	(7,916)	(56.99)
Age2 of HH head	5,255**	9.430	1.043*
	(2,385)	(79.14)	(0.570)
1 if HH sex is male	2.988e+06	14,199	2,033***
	(2.018e+06)	(66,950)	(482.0)
1 if HH head is married	-6.035e+06***	18,923	-142.5
	(1.958e+06)	(64,969)	(467.7)
1 if HH was visited by agrix ext	1.103e+07***	-125,178*	-2,422***
	(1.932e+06)	(64,109)	(461.5)
1 if HH experienced hailstorm	-4.039e+06***	62,133	-2,072***
	(1.468e+06)	(48,695)	(350.5)
HH number of children	-542,422	13,749	-225.1**
	(372,170)	(12,347)	(88.89)
HH size	511,611	-19,763*	33.42
	(338,062)	(11,216)	(80.74)
1 if HH head is a native	2.452e+06*	54,290	1,022***

	(1.428e+06)	(47,378)	(341.1)
1 if HH received input subsidy	2.695e+06 (1.672e+06)	42,021 (55,479)	-1,766*** (399.4)
1 if county has KCSAP	-394,652 (1.145e+06)	-42,291 (37,998)	-415.9 (273.5)
HH head years of education	187,901 (124,190)	-6,379 (4,120)	219.6*** (29.66)
1 if county contact on CSA	4.871e+06*** (1.547e+06)	-85,035* (51,331)	1,122*** (369.5)
1 if HH member of local group	-247,027 (1.322e+06)	326.7 (43,873)	1,182*** (315.8)
1 if HH trained on CSA	-6.654e+06*** (2.290e+06)	14,299 (75,987)	112.7 (547.0)
1 if HH head has access to loan	-3.778e+06*** (1.456e+06)	21,099 (48,299)	2,334*** (347.7)
1 if HH is livestock farmer	2.885e+06 (2.143e+06)	78,623 (71,099)	-2,057*** (511.8)
1 if HH head employed	1.935e+06 (1.556e+06)	13,443 (51,633)	-71.60 (371.7)
1 if HH head own smartphone	-1.177e+06 (1.331e+06)	113,987*** (44,144)	2,009*** (317.8)
Distance to livestock market (km)	57,713 (112,904)	389.5 (3,746)	-83.54*** (26.97)
HH land size (Acres)	20,998 (69,121)	5,049** (2,293)	-7.230 (16.51)
Constant	1.381e+07** (5.958e+06)	88,224 (197,656)	3,284** (1,423)
Observations	672	672	672
R-squared	0.123	0.049	0.502

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A7. Summary of the CSA practices by Agro-Ecological Zones (AEZ).

Group	CSA Practices	Upper Highlands			Upper Midlands			Lowland Highlands		
		N	Mean	SD	N	Mean	SD	N	Mean	SD
Crop Management Practices	Drought resistant crops	85	0.529	0.502	170	0.518	0.501	76	0.487	0.503
	Crop Rotation	85	0.271	0.447	170	0.435	0.497	76	0.382	0.489
	Changing planting dates	85	0.882	0.324	170	0.712	0.454	76	0.697	0.462
	Sequential cropping	85	0.0588	0.237	170	0.124	0.330	76	0.0921	0.291
	Multi season cropping	85	0.800	0.402	170	0.741	0.439	76	0.724	0.450
	Intercropping	85	0.788	0.411	170	0.806	0.397	76	0.776	0.419
Land Management Practices	Use of terraces	85	0.741	0.441	170	0.724	0.449	76	0.605	0.492
	Stone gabions	85	0.0471	0.213	170	0.0941	0.293	76	0.0921	0.291
	Planting trees on crop land	85	0.565	0.499	170	0.600	0.491	76	0.539	0.502
	Use of live fences	85	0.812	0.393	170	0.629	0.484	76	0.618	0.489
	Adoption of cover crop	85	0.200	0.402	170	0.300	0.460	76	0.250	0.436
Farm risk reduction practices	Diversified crops	85	0.318	0.468	170	0.371	0.484	76	0.276	0.450
	Irrigation	85	0.141	0.350	170	0.235	0.425	76	0.237	0.428
	Use of weather forecast	85	0.812	0.393	170	0.547	0.499	76	0.566	0.499
	Insurance (livestock and crop)	85	0.0588	0.237	170	0.0824	0.276	76	0.0789	0.271

Soil and water conservation practices	Planting food crops	85	0.165	0.373	170	0.212	0.410	76	0.158	0.367
	Mulching	85	0.153	0.362	170	0.276	0.449	76	0.250	0.436
	Rain and flood water harvesting	85	0.576	0.497	170	0.524	0.501	76	0.421	0.497
	Application of organic manure	85	0.929	0.258	170	0.824	0.382	76	0.842	0.367
	Integration of legumes	85	0.412	0.495	170	0.347	0.477	76	0.289	0.457
	Efficient use of inorganic fertilizers	85	0.706	0.458	170	0.665	0.473	76	0.697	0.462
Livestock Management practices	Use of plastic silos	85	0.129	0.338	170	0.0765	0.267	76	0.105	0.309
	Use of Muskan milk containers	85	0.259	0.441	170	0.165	0.372	76	0.145	0.354
	Diversification of animal breeds	85	0.082 4	0.277	170	0.141	0.349	76	0.118	0.325
	Improved livestock breeds	85	0.224	0.419	170	0.194	0.397	76	0.158	0.367
	Fodder banks	85	0.129	0.338	170	0.106	0.309	76	0.132	0.340

Table A8. Summary of CSA practices by Agro-Ecological Zones.

Group	CSA Practices	Lowlands Midlands			Inland Lowlands			Coastal lowlands		
		N	Mean	SD	N	Mean	SD	N	Mean	SD
Crop Management Practices	Drought resistant crops	206	0.864	0.344	39	0.0513	0.223	103	0.350	0.479
	Crop Rotation	206	0.549	0.499	39	0.0256	0.160	103	0.233	0.425
	Changing planting dates	206	0.820	0.385	39	0.0513	0.223	103	0.534	0.501
	Sequential cropping	206	0.160	0.368	39	0	0	103	0.0680	0.253
	Multi season cropping	206	0.733	0.443	39	0.0256	0.160	103	0.495	0.502
	Intercropping	206	0.767	0.424	39	0.0513	0.223	103	0.515	0.502
Land Management Practices	Use of terraces	206	0.743	0.438	39	0.0513	0.223	103	0.466	0.501
	Stone gabions	206	0.0874	0.283	39	0	0	103	0.0388	0.194
	Planting trees on crop land	206	0.626	0.485	39	0	0	103	0.369	0.485
	Use of live fences	206	0.782	0.414	39	0.0769	0.270	103	0.515	0.502
	Adoption of cover crop	206	0.350	0.478	39	0	0	103	0.155	0.364
Farm risk reduction practices	Diversified crops	206	0.563	0.497	39	0.0256	0.160	103	0.223	0.418
	Irrigation	206	0.175	0.381	39	0	0	103	0.107	0.310
	Use of weather forecast	206	0.752	0.433	39	0.0513	0.223	103	0.495	0.502

	Insurance (livestock and crop)	206	0.0534	0.225	39	0	0	103	0.0291	0.169
Soil and water conservation practices	Planting food crops	206	0.311	0.464	39	0	0	103	0.126	0.334
	Mulching	206	0.223	0.417	39	0	0	103	0.0680	0.253
	Rain and flood water harvesting	206	0.335	0.473	39	0.0513	0.223	103	0.311	0.465
	Application of organic manure	206	0.917	0.276	39	0.0513	0.223	103	0.602	0.492
	Integration of legumes	206	0.738	0.441	39	0.0513	0.223	103	0.291	0.457
	Efficient use of inorganic fertilizers	206	0.738	0.441	39	0.0256	0.160	103	0.437	0.498
Livestock Management practices	Use of plastic silos	206	0.112	0.316	39	0	0	103	0.0485	0.216
	Use of Muskan milk containers	206	0.141	0.349	39	0	0	103	0.155	0.364
	Diversification of animal breeds	206	0.150	0.358	39	0.0256	0.160	103	0.0485	0.216
	Improved livestock breeds	206	0.306	0.462	39	0.0256	0.160	103	0.117	0.322
	Fodder banks	206	0.214	0.411	39	0	0	103	0.0777	0.269