EFFECTS OF PARTICIPATORY ACTION RESEARCH ON CLIMATE CHANGE ADAPTATION BY SMALLHOLDER FARMERS: CASE OF NYANDO SUB - COUNTY, KENYA

BY

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DECLARATIONS

I declare that this is my original work and has not been submitted to any other College, Institution or University other than the University of Nairobi for academic credit.

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ABSTRACT

Researchers have shown that climate change is a threat to agriculture and rural livelihoods in Africa. It has also revealed that climate change and climate variability have led to increased frequency of droughts, shortening of rainy seasons, and reducing or increasing rainfall amounts. The negative effects are anticipated to be tougher in the warmer regions of African, and that additional increments in temperature will have a bigger consequence on the continent. These regions also happen to be home to the most vulnerable communities; thus, the climate change effects are certainly going to be tougher on the poor, women, and children. Averting this tragedy, calls for transformative farming and land management practices that are adaptable not only to the changing climate but reduce greenhouse gas (GHGs) emissions. Participatory Action Research is one of those approaches where partnership is encouraged at all research levels by involving the target population in developing the research question, methodology designing, data collection participation, analysis and disseminating the findings. The study is aimed at investigating the effects of Participatory Action Research (PAR) among smallholder farmers in Nyando Sub County in Western Kenya, on their adaptation, mitigation and risk management to climate change and variability. The Specific objectives of the study were to identify the existing local farming technologies prior to project implementation, assess the new farming technologies adopted, investigate adoption level of the new technologies and finally to assess the overall effects of the newly adopted farming technologies and practices on livelihoods. A mixed method approach was applied towards getting valid and comprehensive data and ensuring that the study achieved the desired objectives. Data analysis was done using STATA, which entailed the determination of frequency distribution tables, binomial tests and t-tests. A sample of 359 households in Nyando climate smart village was used to explore the effects of the PAR interventions being tested on climate change adaptation, mitigation and risk management. The results indicates that farmers had generally improved their household food security outcomes. Qualitative discussions with farmer groups suggest that households had more secure food conditions during lean seasons unlike before. Baseline primary data had shown that only 5 percent households had own-farm food as a main source during lean seasons. However, this has proportionately appreciated to 14 percent as established by this study. Farmers have generally attributed these outcomes to the diversified livelihood sources promoted through the PAR initiative. These findings illustrate that the PAR contributed to enhanced food security and livelihood conditions among the farmers as attributed by the community during qualitative interviews.

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GLOSSARY OF TERMS

Climate Change	"A change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2007)".
Adaptation	"An adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007)".
Mitigation	"An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2007)".
Risk Management	"An action taken to reduce the risk of disasters and the adverse impacts of natural hazards, through systematic efforts to analyse and manage the causes of disasters, including through avoidance of hazards, reduced social and economic vulnerability to hazards, and improved preparedness for adverse events"
Participatory Action Research (PAR)	"Community-based participatory research is a collaborative approach to research that equitably involves all partners in the research process and recognizes the unique strengths that each brings. It begins with a research topic of importance to the community with the aim of combining knowledge and action for social change to improve community living standards".
Non – Governmental Organizations (NGO)	"A private organization that pursues activities to relieve suffering, promote the interests of the poor, protect the environment, provide basic social services, or undertake community development. In wider usage, the term NGO can be applied to any non-profit organization, which is independent from government. NGOs are typically value-based organizations, which depend, in whole or in part, on charitable donations and voluntary service. Different sources refer to these organizations with different names, such as Civil Society Organizations (CSOs), Private Voluntary Organizations (PVOs), charities, non-profits charities/charitable organizations, third sector organizations and so on (Malena, 1995)".
Stakeholders	"Any group or individual who can affect or is affected by the achievement of the organization's objectives (Freeman, 1984)".

ACRONYMS

CCAFS	-	Climate Change, Agriculture, and Food Security
CGIAR	-	Consultative Group on International Agricultural Research
NGO	-	Non – Governmental Organization
ILRI	-	International Livestock Research Institute
PAR	-	Participatory Agricultural Research
CSA	-	Climate Smart Agriculture
CSVs	-	Climate Smart Villages
HHs	-	Households

Chapter One

1.0 Introduction

According to IPCC (2007) forth assessment report, “climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or because of human activity”.

Climate change and climate variability have severe impacts on welfare and livelihoods of the people directly affected especially the smallholder households. These loses are usually attributed to climate change and variability (prolonged droughts and starvation, excessive rains leading to crop failure, increased pests infestation and crop/livestock diseases.

The current change in climate is largely contributed by human activities, which are capacious to surpass the limits of natural climatic variances *(Karl & Trenberth, 2003*). The impacts of climate change have largely been felt to be significant, nonetheless, predicted to range widely, dependent on socio-economic conditions where it is predicted that “*about 5 million and 170 million additional people falling into risk of hunger by 2080*” *(Schmidhuber & Tubiello, 2007).* Probably climate change, if left unabated, could lead to disruption of advancements toward a hunger free world (*Wheeler & von Braun, 2013*).

It is evident that accelerated climate change and variability have far-reaching effects. It has been projected that there will be a rise in global temperatures by up to 4°C by 2100, with associated variations in rainfall patterns (Thuiller, 2007). It is believed that the African climate is relatively warm compared to decades ago, and is also projected that the trend will likely to continue where temperatures will be higher by more than 1°C by 2025 (IPCC, 2014b). According to IPCC (2007), a warming of more than 1°C coupled with changes in other climatic variables may intensify climate extremes, which may lead to 5 to 8 percent increase of arid and semi-arid lands respectively in Sub Saharan Africa by 2080.

As Morton (2007) states, some of the greatest negative climate change impacts will be experienced by subsistence farmers in developing countries, and Africa being the most vulnerable amongst all, especially because of its high dependency on natural rainfall for food production coupled with lack of adaptive strategies (King’uyu et al., 2009). Morton (2007) concludes by saying that African farmers vulnerability to climate shocks is high in tropics, and where socio-economic, demographic, and policy trends inhibits their adaptive capacity.

At regional scales, the impacts of climate change could be less clear however, it is probable that these changes in climatic conditions and variability will worsen food insecurity in areas already stressed *(Wheeler & Von Braun, 2013)*. In East Africa, probable changes in mean and extreme precipitation have been projected from global climate models whose estimates suggest substantial evidence that there will be a swing in the way rainfall is distributed in East Africa during the wet seasons *(Shongwe et al., 2009)*. Additionally, it has been pointed that there will be greater uncertainties in rainfall patterns for the East Africa region *(van de Steeg et al., 2009).*

In Kenyan context, complex tropical climate varies greatly across regions because of the country's inconstant landscape and multiple regional and global climatic acceleration processes *(MENR, 2002)*. Since 1960 the rainfall levels have been on the decline and it is projected that in the year 2029 some areas of Kenya will experience a rainfall decline of up to 100 mm *(Cooper & Coe, 2011)*. In another study, it is revealed that the rainfall trends have showed varied gestures with some places signifying increasing trends in recent years, while majority have shown no significant trends *(King'uyu et al., 2009)*.

NEMA (2014) suggests that since the last 50 years, 1.0^0C rise in average annual temperatures in Kenya has been recorded and frequent prolonged droughts manifestations in recent years. It is argued that even though Kenya's warm and humid coastal zones, has daily average temperatures varying from 27 – 31 °C *(Mutimba et al., 2010)*, however, approximately 80 percent of it is arid and semi-arid receiving below 700mm rainfall level *(Parry et al., 2012).*

The impact of the declining rainfall will be experienced deeply in the semi-arid lands of Kenya occupying approximately 35% of the total land surface, supporting about 30% of the population (*Government of Kenya, 2009; Herrero et al., 2010*). The declines have also presented new livelihood challenges especially that most of the Kenyan smallholder farmers rely on rain-fed agricultural systems *(Mapfumo et al., 2013).*

Smallholders farmers in Kenya struggle to build resilience to climate change by "*planning for, survive, recover from,* and *even succeed amidst the changing climatic conditions"* – something to contemplate if it is ecologically true as far as outcomes and generalizability. Farmers have started embracing adaptive practices in the face of risks that in itself result into enhanced agricultural productivity; for example water harvesting technologies among the smallholder farmers (Mati, 2000). Specifically in drier environments, rainfall variability is the biggest livelihood risk especially among smallholder farmers who practice rain-fed agriculture (Rao et al., 2011; Zimmerman & Carter, 2003).

This study documents the outcomes of a *community-based, adaptation to climate change through Participatory Action Research (PAR) by smallholder farmers in Nyando Sub County*. an important component of the CCAFS East Africa partnership and research strategy, The CCAFS East Africa regional program commissioned several community based research on *climate change Adaptation, mitigation and risk management in agriculture in the region (CCAFS, 2015). "PAR is a research process that involves community-researcher collaboration and ensures that there is partnership in the whole research cycle, including but not limited to ensuring that the stakeholders (primary beneficiaries) are involved in formulating the research questions, constructing the methodology, participating in the field activities, analysing the results, and disseminating the findings to respective audiences (Minkler & Wallerstein, 2008)"*.

Agriculture sector is dependent on climate parameters hence making it greatly prone to climate change impacts *(Roncoli, 2006)*. Therefore, any change in climate is a threat to agricultural optimal production, with subsequent constrains in local livelihoods globally, especially of rural smallholders that depend on rainfall. Forestalling the challenges necessitates that "*farmers acclimatize by making changes in farming and land management decisions that minimize the negative effects linked with changing climate (Jarvis et al., 2011)*."

Adaptation to changes in climate parameters may minimize general weather risks even though the change might be insignificant. However, it is undeniably true that the negative impacts of the rising temperatures are affecting crop yields as has been witnessed in the past few decades *(Funk & Brown, 2009; Gourdji., 2013).*

It is widely agreed that the negative consequences are likely to become worse in hotter regions worldwide and with far reaching impacts, especially on poorer nations that are dependent on agriculture *(Mendelsohn et. al., 1994; Schlenker & Lobell, 2010; Ericksen et al., 2011; IPCC, 2007; Jarvis et al., 2011)*. Whereas it is a common challenge of the 21^{st} century, climate change will affect different localities uniquely. Marginalized indigenous people located in the remote regions of the world, but contributing less to its cause "*will bear the greatest brunt of climate change" (Green et al., 2010; Tsosie, 2007; UNDP, 2007)*.

Smallholder farmers in SSA that are dependent on rain-fed agriculture are now facing new livelihood challenges *(Mapfumo et al., 2013)*. Unfortunately, the coping capacity to the new and emerging challenges of climate change impacts is hampered by factors such as limited access to new improved technologies and reliable weather information, coupled with limited institutional support mechanisms e.g. policies and institutions for advancing adoption of new technologies and practices. The scenario accelerates the vulnerability of most of small holder farmers in SSA, with resultant food insecurity and malnutrition among households, frequent droughts, flooding and destruction of forested land thereby causing soil infertility and declined natural resource base (Sanchez et al., 1997).

PAR evolved in early 1970's, with the philosophy that the less powerful among the society are put at the heart of the knowledge process (Hall, 1992). As Wallerstein and Duran (2003) puts, PAR is about collaborating with the community by the researcher in conducting the research process. The researcher must answer questions of interest to the community so that they are informed, take corrective action, or create some synergy to change the situation. The community must participate wholly in all facets of the PAR project. The community-researcher collaboration is the key to the success of PAR. As Minkler and Wallerstein (2008) describes, this is *partnership between the researcher and the community in the research process,* including formulating the research questions, choosing the methodology, collecting the research data, analysing the data for results, and disseminating the findings from the PAR.

Hagey (1997) and Wallerstein (1999) have argued that PAR is a more ethical charter for research given that it involves communities in partnering in the research, further highlighting that research is done "with" as opposed to "on" communities. PAR is highly recognized by funders and researchers as an effective approach to doing research as it guarantees equal participation and gives all partners some leverage of ownership on the research outcomes (Wallerstein & Duran, 2003). The PAR builds on assets, strengths and capacities of institutions and communities through collaborative partnership, thus resolving complex societal challenges that are presumably difficult to deal with in certain circumstances. Among the institutions that have extensively, applied PAR is the National Institutes of Health. The reason for its preference is that it is unique in character, and thus creating the roadmap to its implementation in various fields of health research and identification of solutions that address community health burdens. It is also argued that the research is demand driven and the investigators need to incorporate the "main clients" (i.e. the communities) ideas and needs right from the inception stage of the research project.

The "*collaborative nature of PAR lends a more comprehensive and consequently precise framework for common understanding among research partners"*, testing and evaluation of the interventions under investigation by the researchers, which then leads to *"evidence-based interventions or policies"* that are beneficial to the community as argued in the CEAL-UNC collaborative report *(Zimmerman, et al., 2013).* This research approach contravenes other traditional researches undertaken for academic reasons, as PAR increases the depth of evidence-based knowledge. It is argued that the majority of applied research is conducted in the community, but with minimal involvement of the community members whose role is usually advisory. It is assumed that PAR redistributes this power to control and make decisions back to all partners, including the community members, to be equal bearing in mind that "*it is conducted in the community and by the community members"* — thereby termed as "community- based.

Although conducting research in communities has been in existence for decades, e.g. practice-based research networks (PBRNs) which actively involves generating research ideas and conducting research from within the community settings (*Zimmerman et. al., 2013). (Westfall, et al., 2006)* outline the difference between PAR and other research models, and stating that its approach resolves challenges of external validity, language, control of research process by academics, sustainability, and misunderstanding between host communities and researchers.

*Israel et. al. (2005)***,** reckons the PAR pitfalls, stating that it can become more challenging when conducted over a wide geographic area because maintaining an effective communication may not be achieved. However, technology has greatly reduced this distance between partners in a PAR through usage of mobile phones as well as e-mails. While PAR is still at its infancy stages, public health departments have successfully utilized PAR and have achieved positive outcomes. Their successes have been attributed to reliance on PAR's established principles that guide project formation and implementation. Among these include: "*recognizing that community members are partners in the research, utilizing the strengths and resources of all partners, equitable decision-making and control, shared power as well as promoting joint-learning and capacity building across all partners" (Israel et al.*, 2005).

In Nyando Basin of western Kenya, impacts of climate change and variability are already visible. Incidences of frequent droughts, flooding and fluctuating rainfall have reportedly increased, thereby affecting agricultural systems and resultant food insecurity. To further exacerbate the situation, Nyando is a poverty stricken area, coupled with high HIV infection rates among adults (7.5%), thereby rendering the socio-economic drivers to be weak (NACC & NASCOP, 2007). Widow and orphan-headed households continue to dominate in Nyando with lost productivity and labour shortages.

Nyando population is "*predominantly a farming community whose primary source of income and food is mixed crop - livestock system"*. However, their "*farms are not diverse and also show minimal agricultural innovations (Mango et al., 2011)"*. Geologically *"Lower Nyando also suffers serious land degradation where soil erosion is rampant in the two rainy seasons per annum, and surface run off often result into deep gullies affecting about 40 percent of the total landscape (Verchot et al., 2008)"*. The combination of all these challenges, namely: reduced productivity, lost labour, poverty, limited livelihoods diversification and continued land degradation among others leads to increased communities vulnerability to climate related risks, thereby negatively impacting nutritional conditions and food security of households. Earlier study suggests that about 17 percent of Nyando households are incapable of meeting daily food requirements for up to 3-4 months per annum, and there are prevalent malnutrition cases in the community as high as 45 percent among children under-five years (Mango et al., 2011).

Given the gravity of the above challenges, the CGIAR-CCAFS in 2011 started to conduct a PAR in selected villages in Nyando by integrating a science approach to the climate change scenarios using the "*climate-smart village (CSV)"* approach, aimed at delivering development outcomes to the affected community (Kinyangi et al, 2015). CSV is a model where climate sensitive technologies and practices are introduced in a village to better equip the households against climate shocks.

1.3 Statement of the Problem

In Nyando Sub-County, CCAFS and its partners attributed increasing food insecurity to among other things (i) extreme flooding and severe drought, (ii) severely degraded and poor farmlands, and (iii) limited agricultural extension services. These challenges may be addressed through (i) working with agricultural extension services to help with dissemination of improved soil and water conservation practices, (ii) making processes more participatory and community led, and (iii) strengthening of local institutions to enhance adaptive capacity.

This study adopted a case methodology by investigating the PAR project implemented under the CGIAR-CCAFS programme in Nyando, and assessed the outcomes of the intervention as well as contributions of the field-based learning and innovation centres for capacity building of the smallholder farmer's adaptation to climate change. Given that limited adaptive capacity of small-scale farmers to tackle climate change effectively, the project's effort to empower the smallholders to cope, adapt and mitigate against the impeding climate changes was relevant. The study therefore aimed at assessing the effects of the PAR intervention in the project area since its inception in 2011.

1.4 Study Objectives

1.4.1 Overall Objective

The study aimed to investigate the effects of participatory action research on adaptation to climate change by smallholder farmers in Nyando Sub County.

1.4.2 Specific Objectives

The specific objectives of the study were to:

i. Determine the existing local farming technologies and practices prior to the CCAFS' CSV project inception
ii. Analyse the newly introduced farming technologies and practices among households in the CSVs
iii. Assess the adoption level of the newly introduced farming technologies and practices
iv. Assess the effects of the newly introduced farming tecnologies and practices on household livelihoods

1.5 Research Questions

i. What were the previous farming technologies among the Nyando sub-county households before the CCAFS PAR project were introduced?
ii. Has PAR contributed to smallholder farmers' adoption of climate smart technologies? – A model where climate sensitive and risk averse technologies are used on farm.
iii. To what extent have farmers adopted climate smart technologies and practices since PAR were introduced?
iv. Has the adoption of climate smart technologies by farmers led to climate risk reduction, positive food security and livelihood outcomes?

1.6 Significance of the Study

The study will be beneficial to various stakeholders, namely: "*development partners, the government of Kenya, CCAFS, the general public and academic and research community*".

This study will generate insights on the strengths and weaknesses of participatory action research practices among NGOs. This will enable donors to work with NGOs in developing mechanisms that are effective in enhancing *"food security and adaptation to climate change"*.

The government and other policy makers will find the outcome of this study useful in developing laws and policies that are effective in enhancing farmer's adaptation to climate change impacts and thus making the sector's participation in national development more effective.

The research program will use the outcome of this study to provide invaluable lessons from the experiences and practices of its current PAR activities. It will inform current PAR stakeholder efforts that are going well and those not going well. The CCAFS program will develop standards and mechanisms for project implementation.

The key beneficiary of most development aid is the public. The study will enable the public to understand its role in enhancing PAR project implementation.

This study will also be a key contribution to the ongoing discourse on aid effectiveness and particularly the role-played through PAR in climate change impacts adaptation, mitigation and risk management in achieving food security.

1.7 Limitations of Study

Political instability in the region affected the study in the sense that the participating farmers and researchers were not able to implement the interventions in the specified period due to political influence. The region being occupied by two communities of different diverse economic activity, cattle rustling is often witnessed in the area a factor that affected the project negatively.

1.8 Study Scope

The scope of the study focused on assessment of households in CCAFS CSVs in Nyando Sub-County in Western Kenya. It examined the farming technologies and practices of the households as well as the changes that took place since the baseline of the PAR. Livelihood changes and food security outcomes of the PAR intervention were analysed using hunger months.

Chapter Two

2.0 Literature Review

2.1 Introduction

The chapter documents and illustrates PAR practice concepts and principles. It uses empirical and theoretical studies to explain where *"community based participatory action research"* can be applied, discuss its importance and challenges and elucidate measures that can be undertaken to enhance it.

2.2.1 Climate Change in Sub-Saharan Africa (SSA)

"SSA has been grouped among the world's most vulnerable regions to the impacts of climate change" (Hope, 2009; IPCC, 2014a; Kotir, 2011; Kumssa & Jones, 2010; Magrath, 2010; Niang et al., 2014). Africa is projected to be hit worst by global warming in the future, and dry areas expected to get more drier (German et al., 2012). The changing trends in climate and variability have introduced additional livelihood challenges in SSA where smallholder farmers only depend on natural rainfall for agricultural production *(Mapfumo et al., 2013)*.

Arid and Semi-arid regions of Eastern Africa including the coastal areas, as well as many of the southern Africa drier lands predicted that by 2050 will experience an increased climate change vulnerability *(Thornton et. al., 2006; Thornton et. al., 2008; German et. al., 2012)*.

In other studies, impacts of climate change on livelihoods and food security across East Africa has been described as complex due to its highly varied landscapes, and hence poses concern as most of the population is dependent on rain-fed agriculture (Silvestri et al., 2015). Correspondingly, the adaptive capacity of these farmers to such emerging impacts is low, coupled with limited access to information, inappropriate technologies and weak institutions supporting knowledge dissemination (Mapfumo et al., 2013), and as such affects human security (Kumssa & Jones, 2010).

Widespread poverty, unequal distribution of land, heavy reliance on rainfall for agricultural production, recurrent droughts among others factors further accelerates vulnerability of the SSA farmers to climate change and variability impacts (IPCC, 2000). Even though traditional coping strategies exists among smallholder farmers, in reality the economic, human and infrastructural capacity are quite limited for timely response actions for some countries. Consequently, poor access to improved technologies, limited or lack of climate extremes early warning systems, weak extension services, un-harmonized policies governing multi-sectors, weak linkages between research-extension-farmers, poverty at the micro household and recurrent climate extremes (e.g. floods, droughts) increases Africa's vulnerability and exposure to climate change impacts.

Avoiding this challenge necessitates that farmers adapt to farming and land management practices that minimize consequences of climate change. It is therefore important that the ability of agricultural households and that of stakeholders is enhanced in SSA to enable farmers adapt and minimize risk exposure to climate change and variability (Cooper et al., 2008).

2.2.2 Adaptation to Climate Change

Climate change poses a grave threat to food security *(Ziervogel & Ericksen, 2010)*. The impacts caused by climate change have increased significantly in recent years (CCAFS, 2013b), and the need to adapt have increased immensely. The climate change impacts continue to be felt on social and natural systems, while on the other hand the greenhouse gas emissions keep increasing by day *(Wise et al., 2014)*. Climate Change Adaptation requires that *"there is holistic change in processes, system practices or structures, either independent or planned, to minimize possible damage or to take advantage of opportunities connected with climate change (German et al., 2012)"*.

On another hand, food systems adaptations that enhance food security for the vulnerable and prevention of negative impacts arising from climate change in future will demand multiple strategies (Ziervogel & Ericksen, 2010). It may also require "*early investment so that smallholder farming systems are supported and the associated food systems continue to provide poor households with food" (Vermeulen et al., 2012)*.

In Kenya, current understanding, in key sector of agriculture, highlights that investment in adaptation measures such as identifying "*drought tolerant crops, diversification of income opportunities, early warning systems and meteorological information, and water resource conservation planning and management"* (Parry et al., 2012). "*Disaster risk and climate change adaptation"* strategies also been established in Kenya.

Multiple adaptation strategies to climate change have been extensively discussed as detailed in German et al. (2012) and UNISDR (2004, 2009). These include:

Adaptation: **-** Can be described as an adjustment in human and natural systems to response to actual or predicted Climatic stimuli or their effects, which minimize harm or exploit opportunities. Can also be defined as the process by which households increase their ability to cope with climate uncertainties in the future, requiring uptake of appropriate action and make the necessary adjustments to reduce the negatives impacts of climate change (UNFCCC, 2007).

Adaptive capacity: A ability of a system to adjust in the face of the climate change and climate extremes to minimize potential damages, and or take advantage of opportunities, and cope with the consequences of change in climate (German et al., 2012). Adaptive capacity depends primarily on one's access to natural, human, social, physical or financial assets, and how well individuals and institutions utilize such assets. German et al. (2012) continue to assert that those systems with higher adaptive capacity have probable higher degree to recover from or adapt to new conditions. This argument seem supported among researchers, some suggesting that in order to address the climate change challenges, food insecurity and poverty in the tropics demands for enhanced adaptive capacity, mitigation and risk management across Africa's agricultural landscapes (Harvey et al., 2014).

In other words, having better adaptive capacity means that the system has enhanced ability to cope with, recover and decrease levels of exposure to climate change impacts and climate sensitivity. Regions prone to climate shocks require increased adaptive capacity especially the future agricultural systems, as well as ensure that such gains are sustainable as negative climate change impacts are predicted to increase in the near future (Mccarthy et al., 2011).

Vulnerability: IPCC (2001) third assessment report and IPCC (2014a), defines climate change vulnerability as *"the degree to which a system is disposed to, or incapable of coping with the adverse effects of climate change, as well as climate variability and extremes".* Also referred to as a combined function of exposure, sensitivity and adaptive capacity. Equally, personal factors (such as gender, marital status and income) and environmental factors all together interact in determining an individual's level of vulnerability and their adaptive capacity.

Coping capacity: Defined as the "*means by which systems use available and accessible resources and talents to face adverse consequences that could lead to disaster" - UNISDR*. It involves wise management of resources in normal times and during crisis or adverse conditions. It is argued that *"strengthening the coping capacities of individuals and institutions builds resilience to withstand the outcomes of natural as well as human-induced coping capacities"* (UNISDR, 2004; UNISDR, 2009).

In Africa, vulnerability is triggered by multiple factors e.g. high levels of exposure (due to extremely varied climate), sensitivity (reliance on rain-fed agriculture, limited or no access to climate information services on predicted changes, constrained resources access, and various kinds of social disruptions) and inadequate adaptive capacity. Systems cannot easily cope due to factors such as limited economic resources, inadequate infrastructural and technological development, poor local knowledge systems, limited land investment incentives for sustainable gains, weak governance, and misconduct of public resources *(German, et al 2010; Herrero et al., 2010; Tschakert & Dietrich, 2010; UNDP, 2007; Wise et al., 2014).*

Adaptive Management

"Africa's high vulnerability and low adaptive capacity have been linked to poverty and weak institutional framework as well as lack of safety nets" (Herrero et al., 2010). At the same time, there is uncertainty about the rate at which climate change affects various goods, services and ecosystem services and how these will subsequently influence human systems and adaptive capacity (German et al., 2012). It is critical to note that positive adaptation processes and inadequate adaptive practices could unintentionally occur, and thereby reliance on an exact 'best estimates' can have maladaptive outcomes (Green et al., 2010).

Scientific uncertainty has been described as a natural and environmental hallmark and natural resource regulation and decision (Gardner, 2013). This is because of the existence of a lot of uncertainty that surround climate change, including on management systems and policies aimed at enhancing adaptive capacity. Most importantly, the strategy of "adaptation" requires that adjustments are made on social, ecological and economic systems while responding to expected or actual climate stimuli and their effects/impacts (Jameson, 2005).

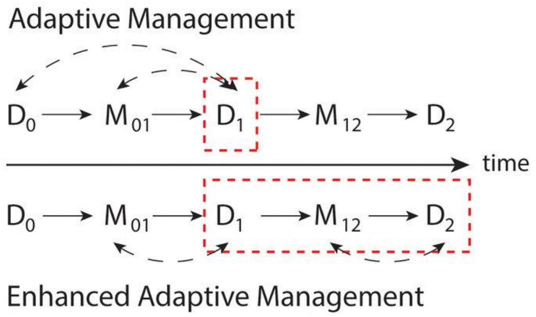
Elsewhere it has been argued by some researchers that, proper adaptive management is considered an effective way for enhancing learning and adaptation by enabling those in management responsibility to house uncertainty and also minimize risk and vulnerability (Gardner, 2013; German et al., 2012). Wollenberg et al. (2016) highlights that, adaptive management is the process by which people incorporate strategic adjustments enabling them to foresee and adapt to changing climate and its variability. Flexibility in decision making is required during uncertainties, experience drawn from past decisions leads to a better understanding of climate events (National Research Council, 2004). Management mediations is used as a tool in probing the ecosystem functioning through determination of climate uncertainties, this is done through identification of methodologies that would best work to test hypotheses surrounding those uncertainties (Abdel-Fattah & Krantzberg, 2014). Such will lead to a change in the system and will promote lessons learning about the system in order to build understanding (Gregory et al., 2006).

Jamieson (2005) points out that adaptation can include "conscious responses to climate change," and can include "non-conscious adaptations" such as incremental responses by farmers to climate variability. Jamieson also notes that some adaptations are "anticipatory," in relation to projected events, for instance flooding, while others are "reactive" in relation to unforeseen natural disasters in a particular community (e.g. hurricanes). It also seems that, adaptive management lacks some logic, as it assumes climate change is foreseeable, implying that managers have only one single choice to make, i.e. you either “adapt to climate change or perish”. Jamieson continue to make a powerful case that a policy of adaptation, without mitigation, will impose "serious practical and moral risks’’. Significantly, adaptive management of natural ecosystems is an interactive process where management decision actions must be followed by focused monitoring (Canter & Hollins, 2005).

In a climate change context, adaptive management entails the knowledge of potential climate impacts and associated uncertainty, which informs the methodology of actions for coping with such uncertainties. Continuous monitoring of climate-sensitive ecological species and evaluation process of the effectiveness of adaptive management use is essential and also iteratively redesigning and implementing improved management options (Keenan, 2015; West et al., 2009; Wilby et al., 2010).

The key elements of adaptive management program largely consists of the collection of information on past and current climatic conditions, prediction of future climate arising from diverse projects and uses, involvement of a wide range of stakeholder segments, use of triangulated models (both quantitative and qualitative models), articulation of management strategic objectives and a variety of management options, designing of a scientifically-proven monitoring systems to track management outcomes to produce consistent and orderly learning that in turn is integrated into successive sets of decision-making, and application of a decision-making tool that is responsive to the explanation of data and inputs from a number of stakeholders and peer-advisors *(Canter & Hollins, 2005; Keenan, 2015; National Research Council, 2004; Wilby et al., 2010)*.

Adaptive management crux is hinged on the principle of learning in a systematic manner where intuition is used in relation to decision making in the light of uncertainties (Doremus et al., 2011, Williams & Brown, 2014). It is a recommended approach in scenarios which require management actions to be taken while the impact knowledge of such actions is limited to the stewards (German et al., 2012).



Source: Convertino et al (2013)

Figure 1: Adaptive Management (AM) and Enhanced (AM) Decision Process

"Adaptive Management: *defined as a focus on sequential decisions with regards to alternative restoration (within the red dotted square) as a monitoring function before the decision and previous decisions (e.g. M01 and D_0). These components constitute the "learning" of adaptive management (dotted arches)" (Convertino et al., 2013)".*

"Enhanced Adaptive Management*: focuses on the best alternative within a strategy that includes a sequence of decisions (at the current time and in the future) and a monitoring plan (within red dotted square). The learning is considered only from the monitoring to consider the incertitude of negative learning, erroneous decision of decision makers (Convertino et al., 2013)".*

"Adaptive management, therefore, is a rigorous process that involves several steps as described in Westgate et al. (2013), namely:

1) Set-up Phase:

a) Identification of management goals and objectives; b) Specification of management options, with one of which can be "do nothing"; c) Development of an assessment process, through the use of conceptual and numerical models and experimental design, to evaluate how the system responds to management actions;

2) Iterative Phase:

a) Implementation of management actions; b) Monitoring and assessment of the system's response to management actions; c) Adjustment of management actions in relation to results; d) Re-visiting goals and objects".

"A key feature of adaptive management is the circular nature of the process in which assessment of climate outcomes contributes to decision-making and adjustment of management actions (Water Institute, 2013)" and the instruments of the adaptive process, and *"some active decision-making about the choice (if any) of adaptive management"* is suitable needs to be explicitly stated (Allan, 2007).

It is defined that evolutionary AM is "*undirected learning from random experience*", best put as *"trial and error learning"*. It is believed that *"passive AM has a strong focus on implementation, precisely the implementation of an historically informed best practice or policy, followed by review of such an implementation"*, in other words an effective evaluation follows the implementation, *"which offers compensation for thinking and reflection, and apposite communication environment for all project stakeholders; and providing mechanisms for including learning into planning and management"*. It is further argued that effective AM is about implementing strategically based on past experience, while encouraging learning from an ongoing implementation (Water Institute, 2013; Allan, 2007).

A central instrument for permitting adaptive management within the framework of climate change is PAR. An example to participatory approach that enhances inclusion of social learning (Gonsalvez, 2013) to adaptive management is the *"adaptive collaborative management (ACM)"*. It is a participatory approach that connects stakeholders, delegates some power to local communities and their subdivisions, and reinforces adaptive capacities (CCAFS, 2013a). ACM *"uses a transformative problem-solving and management style to learn and organize collective action to systematically adapt to climate change and also improve successive management outcomes (Evans et al, 2014)"*. In this way, ACM endeavours to recognize, appreciate, empower and strengthen the local communities' competences in dealing with the challenges they face from climate change impacts (ICRAF, 2008).

2.2.3 Participatory Action Research

Participatory action research (PAR) is a meditative process of broadminded problem-solving led by the stakeholders to improve on problem-solving ability of challenges facing them (German et al., 2012), in other words, a systematic assessment where there is collaboration with the communities affected by the issue under investigation, for purposes of learning and taking precaution, progressive action or implementing the change (Green et al., 2003).

Participatory action research recognises community members as researchers themselves in deriving answers to the questions on things that affect them daily and including their survival (Tandon, 1988). *"It attempts to narrow down the distinction between the researcher and the researched, the subjects and objects of knowledge production by encouraging participation of the people in the process of gaining and creating knowledge over issues that touch on them and their survival"* (Tandon, 1988). In this regard, *"research is envisioned not just as a process of creating knowledge, but instantaneously, as education/learning and development of awareness, and of mobilization for action (Gaventa et al, 1988)"*. It thus enables the disadvantaged groups and subdivisions to *"acquire sufficient creative and transforming control over the situation as deemed in specific projects, acts and struggles" (Fals-Borda & Rahman, 1991).*

PAR is not so different from *"Community-based participatory research (CBPR)"*. In fact, it is a variation of CBPR. CBPR in essence is a collaborative research that is designed to ensure and create structures for participation by common community members especially those been affected by the issue under investigation or research, organizational agents, and multi-divisional researchers to improve the health and well-being of the people through taking collective action, including social change (Zimmerman et al., 2013). PAR is different from Action research (AR). According to German and Stroud (2007), PAR is about "getting change to work," whilst AR is concerned with "understanding the nature of change processes and distilling lessons of use to a wider audience striving to solve similar problems elsewhere."

"There is wide usage of PAR as a research strategy in the field of social and health sciences which has become strongly correlated with the generation of knowledge for action that is believed to have proportionate benefits and use to the targeted stakeholders, for example those living in situations of social vulnerability, disadvantage and oppression" (Amaya & Yeates, 1999).

On health systems, the principle is that by involving grassroots people and health officers in producing evidence-based research and learning, *"PAR has the potential to organize community evidence, stimulate social action, and challenge the relegation that weakens achievement of universal health coverage" (Loewenson et al., 2011)*. CBR in public health places *"emphasis on social, structural, and physical environmental injustices by enabling active participation of the local community, institutional representatives and researchers of various aspects in the research process"* (Hagey, 1997; Israel et al, 1998; Nina Wallerstein & Duran, 2010)

Comparatively, since PAR emphasizes on collective learning and on repeated cycles of planning, taking relevant action, monitoring the outcomes, reflecting and re-planning, PAR is therefore viewed as an instrument distinctively suitable to supporting climate change adaptation (German et al., 2010). German et al (2010) highlights that it combines two basic activities, namely: participatory research and an aided process of social learning directed by a common vision or strategic objectives to be arrived at.

Principles Governing Participatory Action Research

It is extensively synthesised by Israel et al. (1998) in their research literature on community-based and participatory action research, that for PAR to succeed, the following key principles of community-based research should be applied. Although these below discussed principles were relevant in the field of community-based public health research, they could also act as a good starting point in other community-based researches, including climate change, although not definitive. The principles include:

i. *"Community recognition as a unit of identity: - where the researcher should work explicitly with communities, either defined by a geographic boundary, or geographically dispersed but whose members subscribe to a sense of common identity and shared vision".*
ii. *"Building on the strengths and resources available from within the community: - The research should clearly recognize, support and strengthen social organizations, processes, and indigenous knowledge already prevailing in the community that motivates them to work together to improve their lives".*
iii. *"Facilitate collaborative partnerships in the research cycle: - The research must incorporate participation of the community in all its phases where possible. For example, including them in the problem tree and objective tree design (problem definition, needs assessments/resources mapping, data collection processes, data analysis and interpretation of results, as well as application of research recommendations to address community concerns. Although involvement of applicable skills from outside of the community is encouraged, but it should explicitly concentrate on issues identified by the community and create avenues in which all parties can actually influence the whole research process".*
iv. *"Integrating knowledge and action for shared benefit of all stakeholders: - All parties concerned must have the zeal of committing themselves to applying the identified research solutions to the social problem, although there may be no immediate action points of the research".*
v. *"Promotes collaborative learning and addresses social inequalities: - The research must identify the inherent inequities between downgraded communities and researchers, and should endeavour to address such by underscoring knowledge of community members and sharing information, resources and decision-making power. In this way, the researchers learn from the local knowledge and indigenous theories existing in the community, and vice-versa community members acquire additional skills in conducting research and identifying solutions to problems that affects them".*
vi. "*Entails a cyclical and iterative process: - The research process should encourage trust building, partnership development and continuous maintenance throughout the research cycle."*

vii. *"Disseminate research findings and knowledge acquired to all partners: - The research findings should be disseminated to all parties involved, but in a respectful and understandable language, while acknowledging all participants contributions and ownership of the knowledge production"*

2.2.4 PAR for Climate Change Adaptation and the role of Climate Smart Villages

The *"CGIAR Research Program on Climate Change, Agriculture and Food Security*" is working collaboratively with a wide range of partners in testing different interventions using climate-smart village model. In East Africa, CCAFS is testing PAR where it has identified research sites in Uganda, Ethiopia, Tanzania and Kenya as Climate Smart Villages (Figure 4).

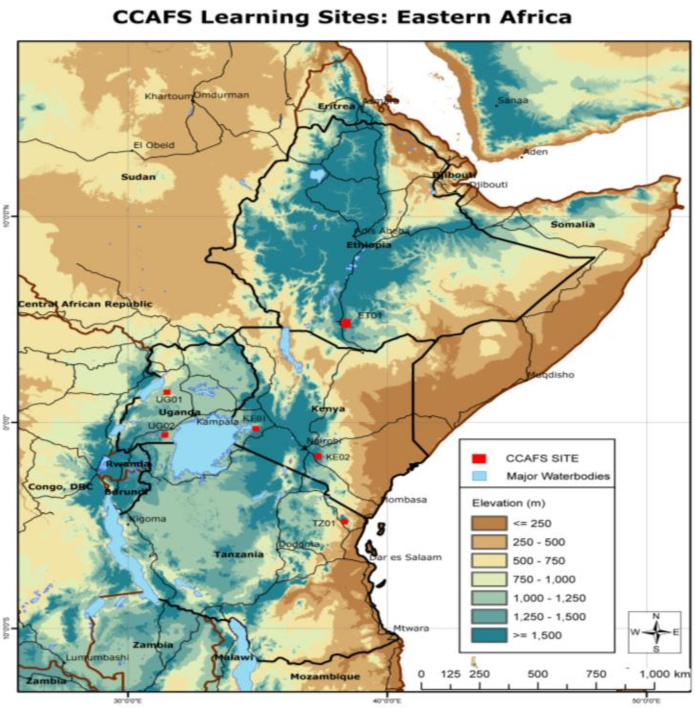
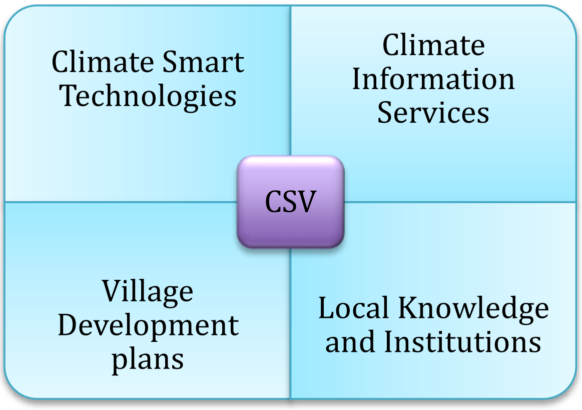


Figure 2: A map showing CCAFS East Africa Learning Sites

As alluded to elsewhere in this study, CCAFS being a research for development collaboration between the CGIAR and the global change community, scientists globally are working on environmental and climate change issues in several institutions and programs (Vermeulen et al., 2012). CCAFS is also involved in identifying and evaluating the outcomes farmers get as they strive to address risks caused by climate change and variability, and the implications thereof for household food security and national food security conditions (Jarvis et al., 2011).

Conceptually, a climate smart village (CSV) is defined as a *"community approach to sustainable agriculture by enhancing adaptation, mitigation and climate risk management* *among the communities in order to build climate change resilience and attain household food security"*. In the CSV, *"farmers are engaged in testing Climate Smart Agricultural (CSA) practices"*. CSA approach is hypothesized that it *"sustainably increases productivity and resilience (adaptation), reduces or removes GHGs (mitigation), and enhances achievement of national food security and development goals"* (FAO, 2010). It is perceived as a *"set of practices – especially those that have been tested for local appropriateness – that can improve farmers' climate change adaptation or intensify the mitigation potential of production through carbon sequestration or reduced emissions, while at the same time meeting or surpassing food security goals"*.



Source: CCAFS (2010)

Figure 3: Components of Climate Smart Villages

The key components of CSV are the adoption of climate smart technologies, which incorporate the climate information services contributing to village development plans using the local knowledge and local institutions. These enhance improved agricultural production, income generation and building climate resilience and adaptation at household level.

The East Africa farmers have faced with high rainfall variability in recent decades, within and between seasons, which has caused farming systems to change over these past years (Cooper & Coe, 2011). Farmers have been testing and adopting new agricultural practices as a means of adapting to climate variability. Ideally better coping mechanisms in the face of these climatic variability by the farmers is critical to adapting to future climate change (Cooper et al., 2008). Among the changes introduced by the farmers in agricultural practices, includes: improved crop, soil, land, water and livestock management systems. More particularly, the farmers are seen practicing crop cover, micro-catchments, ridges, rotations, improved pastures, planting trees, and other evolving techniques such as planting of improved seeds, shorter cycle varieties, and drought tolerant varieties. It is believed that such farming practices have a direct link with adaptation to and coping with climate variability (Adejuwon, 2006; Hellmuth et al., 2007). Elsewhere it has been reported that diversified options at the household level is vital for income and household food security. It is argued that households that practice more cropping as well as non-agricultural activities tend to adapt better than those engaged in fewer (Thornton et al., 2007; Thornton et al, 2011).

The efforts to increase agricultural productivity, but subsequently minimizing environmental footprint of agriculture, is critical in addressing food security (Obersteiner et al, 2010; UNEP, 2008). Ericksen et al. (2009) underscore the importance of practicing integrated food system approach, which promotes food production in a sustainable manner with less environmental destruction. Additionally, understanding the variability and volatility on food prices, as well as appropriate governance of food systems is critical in safeguarding households in the face of increasing food insecurity (Ericksen et al., 2009).

The *"CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) implements its program activities globally in West Africa, East Africa, South Asia, South East Asia and Latin America"*. Participatory action research (PAR) is a key element of the CCAFS East Africa partnership and research strategy. The PAR process is *"centred on working with communities at the grass root level to identify and implement activities that will help build a resilient food system. The PAR process is characterized by cyclic planning-action-reflection processes (German et al., 2012) that aids in the establishment of local capacity gaps for which external support can be canvased (e.g. professional knowledge, relevant technologies and financial inputs)"*. The PAR approach comprises of participatory stock-taking and identification of constraints, opportunities and needs, identification and definition of adaptation and mitigation priority options, testing and validating of selected technologies and practices by men and women farmers and the youth and continuous monitoring and evaluation

The solution lies in PAR in order to ensure sustainability of CCAFS projects. PAR as explained by (Wallerstein & Duran, 2010) has evolved in the past decades as a transformative research practice that overcomes the inequality between scientists and community members by encouraging community participation and social action. More specifically, there must be local engagement with the community heads and investment in empowering potential project "champions" who may continue with the implementation of the project, even after funding and technical support has been withdrawn. Project impact and sustainability is dependent on initial planning and effective stakeholder analysis (UNDP OESP, 1997).

CCAFS therefore recognizes such PAR attributes as crucial for instituting adaptive capacity of farming communities affected by climate change. In this pursuit, farmer experimentations that are field-based were established. This acted both as a diagnostic tool and as an instrument of participatory evaluation. In this implementation process, interactive learning happens between farmers and researchers of the PAR. Along the way, new agricultural technologies that are already field-tested are introduced, and evaluated by the farmers in light of the previously existing practice(s) or other known alternatives. Field-based learning occurs in this process; farmers interact with the researchers, evaluate and allow practical integration of diverse knowledge sources of partners in order to address complex problems.

2.3 Critical Literature on Climate Change

It has become extensively understood that global climate change is indeed happening and thereby impacting economic growth, food security and rural livelihoods (German et al., 2010). At the same time, PAR is fast becoming recognized due to an increasing demand on research technology uptake and impact (Amaya & Yeates, 1999). It is believed that participatory research underscores stakeholders as important agents who contribute diverse knowledge and techniques, and places emphasis on ownership of research findings and such research outputs that are likely translatable into action.

Climate change has been pinned as a cause of threat to agriculture for some decades now in Africa (Rhodes et al., 2014). The most vulnerable to climate change are the smallholders since they do not enjoy sufficiency of resources and information to enable them to effectively develop response strategies (Western Cape Government, not dated.).

In a research by Sarr et al. (2015) it was found that smallholders' knowledge, skills, and aspirations about managing climate change are vital. In their work in Burkina Faso, Chad and Niger, it was established that strategies such as: "*expansion of irrigation systems, adjusting crop planting times to suit localized weather and climate forecasts, plant breeding to establish more heat-stress tolerant crops and associated agroforestry*" were very relevant and useful to climate change adaptation. Sarr et al. (2015) reveals that farmers from these 3 countries are careful observers of climate variability and change; but also use climate adaptation measures to avert climate risks. Similar studies in southern Ethiopia revealed that farmers were aware of these climate changes and their consequences (Debela et al., 2015).

A study by Deressa et al. (2009) identified the main methods used by farmers to adapt to climate change in the Nile Basin region of Ethiopia. The methods identified included "*use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation*", similar to methods used elsewhere by farmers outside Africa in order to adapt to climate change e.g. change of crops (Seo & Mendelsohn, 2008). Deressa et al. (2009) established that the main barriers to climate change adaptation included lack of information on appropriate adaptation methods and financial restraints.

In Zimbabwe, Chikozho (2010) found that climate change and climate variability poses threats to rain-fed agricultural communities in the semi-arid agro-ecological zones, and the impacts were undermined, mainly due to unpredictable seasonal rainfall, floods and cyclones. The researchers went further to establish that adaptation to the climate change impacts are increasingly being advocated for as a means to responsive and sustainable enhancement of livelihoods.

Mapfumo et al. (2013) documents that *"PAR was successfully been used for empowering communities to self-mobilize and self-organize to co-learn and equally experiment with integrated soil fertility management (ISFM) technologies and other improved farming practices*". It was further identified that the *"PAR drives effective partnerships among community members, extension, policy makers and researchers".*

In yet another research on vulnerability of smallholder farmers to climate variability and change by Rurinda et al. (2014), it investigated and found *"no evidence of a standalone one-to-one relationship between vulnerability and household resource base, thereby suggesting that vulnerability is a complex and not directed associated with productive and non-productive assets of the household".*

Rurinda et al. (2014) study further highlighted that farmers were also faced with biophysical and socioeconomic challenges such as lack of fertilizers, which had strong associations with adaptation options to climate change. Calls for diversification of crops and cultivars, staggering planting date and management of soil fertility were recognised as the main adaptation options if farmers were to produce steady and sustainable yields in the face of increased rainfall variability. In another study in Zimbabwe, it was identified that incorporating local context while developing adaptation strategies is key in dealing with such climate change challenges (Brown et al., 2012).

Brown et al. (2012) advocates for participatory methods in addressing climate change, namely: *"1) engaging traditionally marginalised groups (particularly women); 2) identifying the diverse needs of farmers and exposing them to as many adaptation options as possible; and 3) instilling a sense of ownership in the project among participants"*, thereby increasing the chances of project success and ownership.

Similarly, in Madagascar, a research on climate change and agrarian systems by IDRC (2012) revealed a stream of dialogue, similar to PAR, where remote sensing and other diagnostic techniques were deployed in predicting climate variability, and this helped in identifying livelihoods that were most at risk, and the climate conditions that presented these risks.

In a study by Tschakert & Dietrich (2010), it was found that iterative and cyclical structure in reflection–decision–action process underpins weak and vulnerable communities to transform their current undesirable situations into more desirable and resilient futures, while recognizing their rights and skills to decrease harm and avoid unwanted levels of such harm by accommodating their imaginations and prepositions.

In Morogoro Tanzania, "*agricultural households have responded by adapting extended/prolonged cultivation, intensified agriculture, diversified livelihoods and migrated to gain access to land, markets and employment as a response to climatic and other stressors*" (Paavola, 2008).

At the national level, "*climate adaptation for agriculture begins with macro-policies, regulations and institutional reform. Emphasis is placed on adaptation strategies that can be cross-sectorial in scope involving agriculture, health, energy, water infrastructure (i.e. irrigation) and rural financial services (banking)"* (FAO, 2015).

Africa has been identified as arguably the most vulnerable region in the world to the impacts of climate change (African Development Bank Group, 2011). It is sufficiently useful to note that effective attainment of PAR principles and approaches by grantees is needed, and their better understanding of how to implement adaptive processes in the field is strongly recommended (German et al., 2010).

PAR is useful in triggering technological, social and institutional innovation in Africa to enhance smallholders' adaptive capacity to cope with climate change and increased climate variability. Owing to that, PAR increasingly offers significant advantages over the conventional research model whereby research products are passively transferred to smallholders through extension workers (Francis T & Habtamu, 2012).

A critical look at PAR by Francis and Habtamu, deems PAR-increasing use to have brought about very different but positive outcomes at the various sites they reviewed, but then compared favourably to the "failures" often reported from other alternative approaches in the past in Africa. However, they contend that the major challenge remains how to sustain the level of engagement and support needed to facilitate a transformation of extension, local leaders and service providers towards institutionalization of the approach. IPCC (2007) also highlights that ‘‘*African farmers have developed several adaptation options to cope with current climate variability, but such adaptations may not be sufficient for future changes of climate (high confidence) IPCC (2007)*”.

2.4 Conceptual Framework

From the theoretical review, it is apparent that integrating climate adaptation within agriculture, at smallholder level needs a suitable framework able to effectively combine the environmental and socioeconomic dimensions in a rational, complementary and interlinked way. As already seen in this study, climate change is a widely used term in policy making, development advocacy and in academics. According to Kalungu (2014), it is a “change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer” that may arise from internal processes and or the external forces that are traceable to human activity. Until this end, a more action oriented and pragmatic research seems a feasible approach in trying to establish adaptation options as climate change is already evident. Given that its socio-economic and environmental implications are far-reaching (although varied), a more qualitative and participatory inquiry on how human populations are adapting and how these are influencing food systems and sustainability needs to be explored. This therefore became the methodological approach of this current study.

While Climate change impacts are “*the effects of climate change on natural and human systems”* (IPCC, 2007), climate change itself has been described by IPCC as “*a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer*” (IPCC, 2007). The focus of climate change action research is “*to evaluate the broad trends in agricultural productivity impacts, resource availability and future land use, as well as the likely impacts of climate change and their relative magnitude at the global level”* (FAO, 2015). This involves disaster risk reduction, i.e. “*the conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broader context of sustainable development*” (UNISDR, 2004).

According to FAO (2015), at global or regional levels, climate actions/adaptive measures entails climate crop impact assessments (climate models, bio-physical analyses, geospatial data with adaptation strategies such as water, energy, land-use, fertilizer, input/resource planning. While at the sector-level, climate adaptation involves assessment and policy action (smallholder); at the farm-level, it involves climate-smart agriculture (CSA); adaptation technologies; diversification; capacity, resilience. Technology here is the "*practical application of knowledge to achieve particular tasks that employs both technical artefacts (hardware, equipment) and (social) information ('software', know-how for production and use of artefacts)*" (IPCC, 2007).

The conceptual framework interlinks the study objectives of determining the existing local farming technologies and practices prior to project inception, establishing the newly introduced farming technologies and practices associated with the CCAFS project, appraise the adoption level of the newly introduced farming technologies and practices and assess the effects of the newly introduced farming tecnologies and practices on the livelihood sources within the framework of CSV and CSA and outcomes of PAR on smallholder farmer adaptation to climate change in the study area.

This study adopted an innovative framework that combines elements of socio-institutional, environment (biophysical) and economic aspects (FAO, 2015) for smallholders. The conceptual framework is built on elements of CSA and CSV of CCAFS and focused on PAR adaptation integration at the smallholder level.

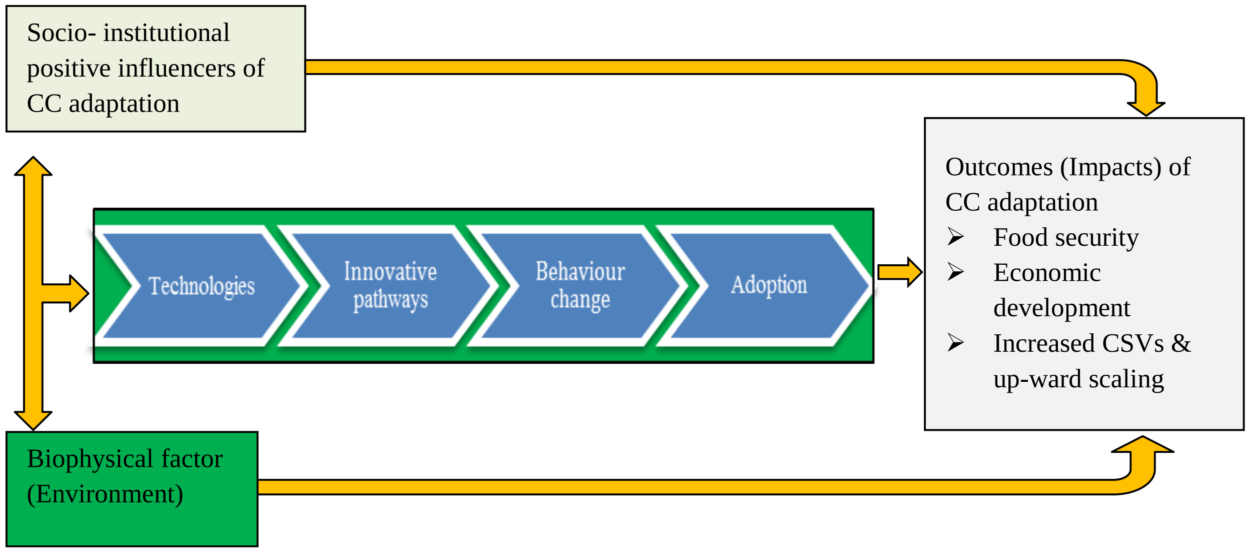
Biophysical (environmental) involves agricultural system needed to understand the agronomic, agro-ecological and geospatial impacts of climate change and measure the technical scope for adaptation. Biophysical includes land, water, climate, GHG emissions and biotic dynamics. Biophysical will have effect on climate impact on crop yield (temperature variance, rainfall), geo-spatial and land use suitability for cropping systems, climate impact on water resource management, climate biotic (disease/pests) impacts on crop systems among others. Here it entails crops (diversification; drought escaping and tolerant) for food security (climate impact on crop yield (temperature, rainfall), livestock (disease resistant, diversification) for food security and reducing GHGS).

Socio-institutional addresses the critical issue of social structures, organizations, power relations and governance. Such socio-institutional analysis is also required for their uptake to ensure social acceptance and inclusive policy decisions. On a wider scope it entails system social indicators (income, employment, health), access to resources, information and know-how, institutional support structures (group resilience), inclusive governance and participative processes, infrastructure and other coping mechanisms. Here they include social innovations for investment in agriculture (building social resilience and managing risks), agro-advisory and climate information services (to improve farmer decision making and building resilience).

Economics involves agricultural production (source of comparative advantage), yield (productivity), prices, cost structure (input use efficiency, technology), market structure (value added distribution), demand drivers (consumption, trade).

Below is the study conceptual diagram depicting the interaction between socio-economic, institutional and biophysical variables resulting into climate smart desired socio economic and food security outcomes within a climate smart village. This conceptual model is built on the assumptions that: social innovations for investment in Agriculture builds social resilience and ability to manage risks; and that agro-advisory and climate information services leads to improvement in farmer decision making & building of resilience; Crop improvements (diversification; drought escaping and resistant varieties) are made for food security in the face of severe climate challenges (prolonged drought, floods); and lastly, livestock improvements (disease resistant, diversification) for food security and reducing Green House Gases (GHG)

<u>Conceptual Model for the study</u>



Source: Author's own

Figure 4: Study Conceptual Model

Where: CC = Climate Change

CST = Climate Smart Technologies

CIS = Climate Information Services

LKI = Local Knowledge and Institutions

VDP = Village Development Plans

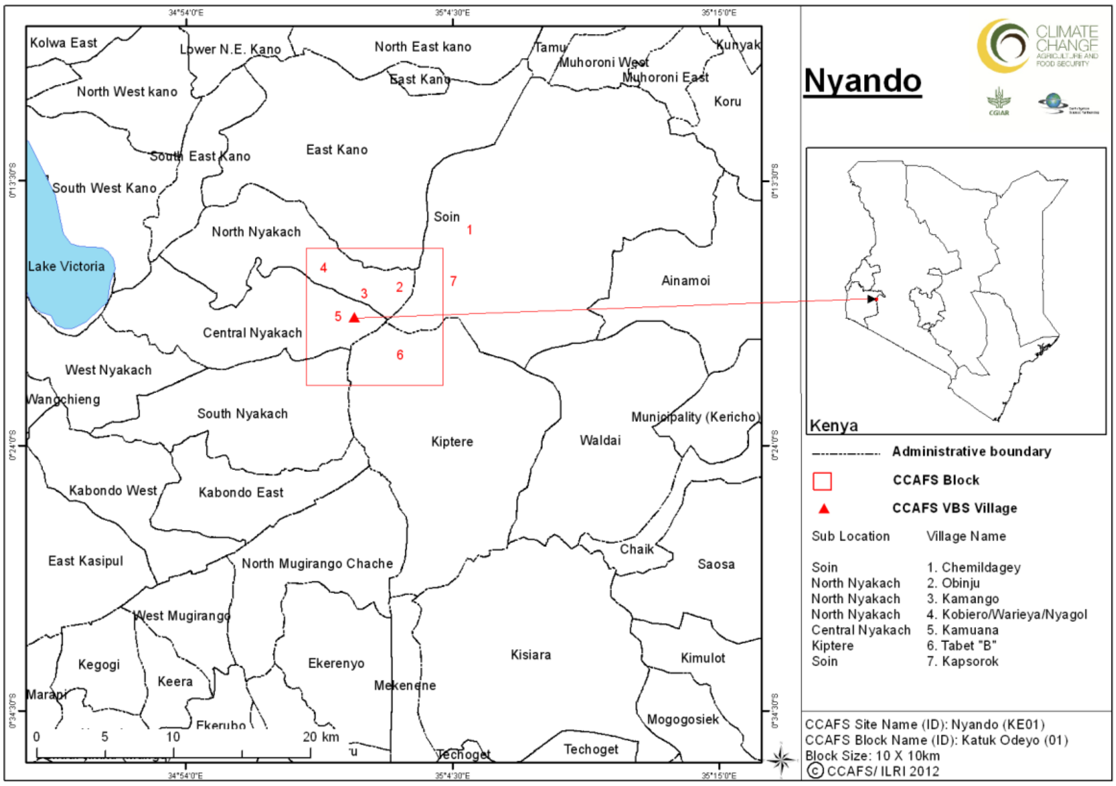
Chapter Three

3.0 Research Methodology

This chapter discusses the study discusses the study area, research design, population size and sampling design, data collection methods, research procedures and data analysis methods.

3.1 Description of the study area

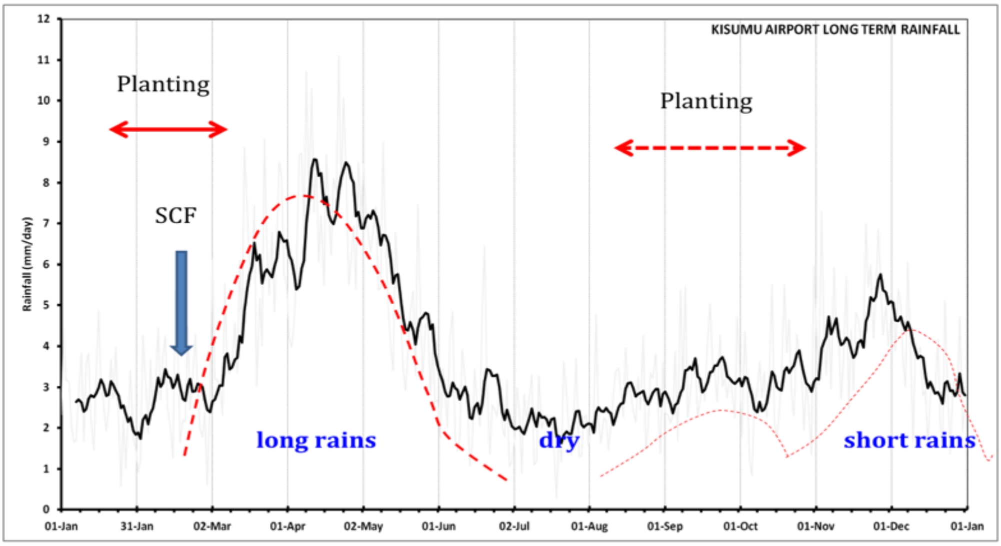
The study was conducted in Lower Nyando of Nyando District in Kisumu County in Western Kenya (Figure 5). Topographically a low-lying area experiences frequent extreme flooding events. In terms of rains, the area receives biannual rainfall pattern with an average of less than 1,440 mm per annum (Figure 6). The long rainy season occurs between March and June while the short rains come between September and November, with high temporal variation coefficient of 25 percent (Recha et al., 2017). Since 2000, the area has received a declining rainfall with 2014 registering the lowest amount on record. This continuous reduction is believed to be caused by destruction of water catchment areas at the upper Nyakach coupled with reduced forest cover in Nyando (Recha et al., 2017). Temperature-wise it is indicated that "*the average annual temperature in Nyando during the period 2001- 2010 was 0.067°C higher compared to the period 1981 to 1990*", a clear sign of climate change (Recha et al., 2017).



Source: CCAFS East Africa 2015

Figure 5: The Map of Nyando showing study CSVs

In terms of soil type, the Nyando river basin has "*dark coloured clays and clay loams that are the most widespread of the alluvial soil types. Lower Nyando suffers serious land degradation where soil erosion is rampant in the two annual rainy seasons, and surface run off forms deep gullies that affect about 40 per cent of the landscape*" (Obiero et al., 2012).



Source: Kisumu Meteorological Department

Figure 6: Rainfall trend in Lower Nyando

Socio-economically, the population largely comprises of agro-pastoralists whose production system is mixed crop-livestock rearing. There is reportedly high poverty (half pop. below poverty line) coupled with prevalent HIV (adult infection rate of 7.5%) leading to more widow- or orphan-headed households, lost productivity and labour shortages. Farming is Nyando's primary source of income and food (a mixed crop-livestock system) with undiversified limited agricultural innovations (Macoloo et al., 2013). It is reported elsewhere that up to 17 percent of households are not able to meet their daily food requirements for a total 3-4 months per annum, with malnutrition estimated to be 45 percent among under-fives. Such conditions only gravitate communities into climate risk vulnerability thereby reducing household food supply and nutritional status (Obiero et al., 2012)

3.2 Research Design

This study was comparative in nature, comparing the baseline conditions of the CSVs in the project area where the PAR was implemented. The study collected data both qualitatively and quantitatively based on the objectives of the research, estimating and quantifying the use of farming technologies and the establishment of the relationships between these technologies and main livelihood sources of the communities, as well as the food security status of the households.

3.3 Target Population

The farmers of Lower Nyando Basin in western Kenya, one of the climate smart villages chosen by CCAFS, constituted the population of interest in this study. The approximate household population of the CSVs in Lower Nyando is about 30,000 households according Kinyangi et. al. (2015). These households are mainly agriculturalists and some agro-pastoralists who largely depend on mixed crop and livestock farming for their regular livelihoods.

3.4 Sampling Design

3.4.1 Sample Size

The Pagoso *et al.* (1980) statistical formula was used to determine the study sample size.

$n = N/(1+Ne^2)$ …………………………………………………………………… (1)

Where n = minimum required sample size

N = Study Target population

e = margin of error (max 0.05)

The approximated household population in the CSVs in Lower Nyando was approximately 30,000 (Kinyangi et. al. 2015). The sample size estimated from the above formula approximated to 395 households for the survey. Data was collected from 395 households, although only 359 questionnaires were valid for data needed while the rest discarded during cleaning due to errors.

3.4.2 Sampling Frame

The study was a cross-sectional Participatory Action Research (PAR) monitoring survey carried out in 2015 following an earlier baseline survey that was conducted in 2011. This formed the basis of a comparative analysis of agricultural practices and technologies between the two time periods while investigating the household food security and livelihood outcomes as a result of these changes. A multi-stage sampling design was used to identify respondent households into the study. Firstly, a geographical stratification of the study area into sub-locations was performed, followed by a selection of clusters (villages) within each stratum, and then a random selection of households within each cluster in the CSVs. Within each sub-location, seven villages were randomly selected and then coded households were randomly chosen from a list of households in each village using a randomizer (www.randomizer.org). Probability to Proportion Sampling (PPS) (i.e. proportionate representation from all clusters) method was used to select households per village in each of the sub-locations. This was to minimize chances of oversampling/under sampling in some CSVs but maintain equal representation proportionately from all villages in the study sample.

3.5 Data Collection Methods and Instruments

The study collected primary data by means of questionnaires and personal interviews that involved enumerators visiting the randomly selected respondents at their respective homes, reading questions to them from the paper questionnaires and recording the answers. Both open (questions for discussions) and close-ended (with choices) were used, thus ensuring collection of enough information necessary to achieve the research objectives. In order to examine any changes between the past and the current household situation, a desk review analysis of the baseline report (2012) was conducted in order to derive insights on the pre-PAR intervention conditions among the households. This was done simultaneously with the monitoring data analysis. Details of the data collection methods are discussed below:

Desk Review: A desk review of the baseline data and baseline report was done inorder to inform the present study of the pre-existing conditons before the implementation of the PAR in Nyando. Key indicator reference points were identified, against which the study indicator levels were compared to assess for any significant changes. A review guide was developed for extracting information from the baseline report, as well as actual analysis of the archived baseline data.

Household Survey: Household interviews were conducted with beneficiary households of the PAR in lower Nyando. Adoption of the proven technologies and practices, livelihood changes as well as food security among others were assessed through household survey, guided by the sampling frame of the PAR annual monitoring which targeted project households from 7, randomnly selected, villages in Lower Nyando. A household questionnaire was used for data collection from the beneficiary households in the CSVs.

Key Informant Interview: - Interviews were held with CCAFS project staff, Nyando Sub-County agricultural officers, forestry and environment officers. These interviews were conducted in order to establish the exact technologies been introduced by the PAR project and further discuss the technical and socio-economic viability of these technologies and practices in the project area. Interview guide was developed for data collection from key informants.

Focus Group Discussion: - Discussions were held with farmers groups to discuss the climate smart agricultural technologies and practices, and how they evaluate the relevance and effectiveness of these introduced techniques. The discussions were also meant to understand if these practices would remain sustainable should the CCAFS project discontinues to support PAR activities. Group discussion guide was designed and adopted for data collection from FGDs.

Group Interview: - To further complement the FGDs, group interviews were held with sample farmers in CSVs to discuss the wider perspectives of beneficiary farmers in Nyando Sub-County, and understand how these technologies are being adopted, and the extent to which they are cross-cutting issues of vulnerable farming communities, including orphaned households, HIV AIDS and female headed households. Interview guide was developed for data collection from such group interviews.

Observational Method: - The study also utilized observational data collection method to analyze existing agricultural technologies been adopted by farmers in the CSVs in Nyando Sub-county. Observational checklist was developed and used for data collection while visiting farms in the CSVs.

3.6 Data types and management techniques

3.6.1 Data types and sources

Quantitative and qualitative data types originating from primary data collection processes as well as secondary sources were utilized during this study.

Annual monitoring primary data collected in 2015 for review of the CCAFS PAR project was adopted as the main primary source of data. Data on crop production was mainly on crop and seeds types, fertilizer use among households, soil and land management techniques, crop yields, domestic consumption, and sale for income. Data on livestock included types of livestock kept, changes made in livestock, livestock products, consumption on farm and sale for income. The data obtained also covered alternative sources of cash by the household, access to climate and weather information, agro-forestry and tree planting and or conservation. Additionally the study collected data on food security, as well as relative changes in livelihood sources.

Climate data for Kisumu Airport station was obtained from Kenya Meteorological Department for analysis in order to obtain changes over the past decades assess anomalies and what households did in order to cope with the gradually changing climatic conditions and how the CCAFS PAR project complemented household coping and adaptation efforts.

Secondary baseline data from CCAFS which highlights the various sources of livelihoods (on and off – farm), crop, farm animals, tree and soil, land and water management changes, food security and climate and weather information.

Additional secondary data from previous CCAFS monitoring reports, partner visit reports on project area and other documents on the PAR in Nyando Sub-County were reviewed in order to complement the primary data findings and discussions.

3.6.2 Data Management techniques

Data entry and management was conducted using the Census and Survey Processing (CSPro) software technology (developed by the United States Pop. Census Bureau). CSPro is a widely used data management software application suitable for entering survey data, collating, editing, tabulating and disseminating Census and Survey data. The raw filed questionnaires were manually crosschecked for any errors, and then entered using the double entry method in CSPro in order to identify errors in entry by either of the two independent data clerks. The data was then examined for human errors, cleaned and managed electronically using the same CSPro application. The final cleaned data was exported to STATA (v14) statistical software for further data organization (reshaping and manipulating the data) before embarking on full data analysis.

3.7 Data Analysis Methods

The analysis of the described data types (section 3.6.1) were analyzed using the following methods as guided by the study objectives:

a) To determine the existing local farming technologies and practices prior to the CCAFS' CSV project inception:

Analysis of the study objective was achieved by qualitatively reviewing the project secondary baseline report and identifying the households farm production levels, farming practices and technologies used in 2011 (PAR project inception). Additionally, livestock production systems and outputs were qualitatively established from the baseline report. Household food security conditions were also explored as reported in the baseline findings. This was to provide an understanding of the initial conditions of the households prior to the PAR interventions.

b) To analyse the newly introduced farming technologies and practices among the households in the CSVs:

Descriptive analysis of the 2015 PAR monitoring data was conducted. Project effective activities and introduced technologies were identified from project reports, KIIs, FGDs and beneficiary household interviews. It was analysed using thresholds (confirming presence or absence of introduced technologies among the farmers) and qualitatively discussed and presented in the results section (chapter 4).

c) To assess the adoption level of the newly introduced farming technologies and practices:

Uptake and adoption levels were analysed quantitatively and descriptively by establishing the total count of farmers, practicing introduced technology from interview dataset. The results presented in tables and chi-sq. proportional intervals estimated of the total number of farmers adopting relative to the sample population. The nature of adoption was also qualitatively analysed using FGD and KII dataset, and the results presented.

d) To assess the effects of the newly introduced farming tecnologies and practices on household livelihoods:

Household data on food security and livelihoods was analysed using household hunger months and number of months the household is food secure in a year. These were further discussed in light of the changes in climate and the adaptation technologies the households have tried to use in order to cope with the changing climate. In order words, the study adopted descriptive analysis in describing household food security situations as opposed to regression analysis for causative searches on whether the changes in food security outcomes are truly because of the adopted technologies and practices. Comparative analysis of what the situation was the food security situation before the project and what it is at the time of this research was conducted.

Chapter Four

4.0 Study Results

This chapter presents the findings of the study. The first section documents the demographic characteristics of the study target population. The second section presents the local adaptation practices and technologies towards climate change impacts by farmers prior to the PAR project in Nyando. The third section illustrates the climate change adaptation farming practices and technologies among the beneficiary households as at the time of this study. The fourth section documents the level of adoption of the PAR introduced farming technologies and practices. The fifth section describes the PAR project outcomes among the target households in Nyando.

4.1 Household Demographic Characteristics

Majority of the households in the study area were male-headed (63%). Ethnically the population is constituted by 57 percent - Luo and 43 percent - Kalenjin (Table 1). The average household size is about five per household (Table 2). Seven percent of the households at least have vulnerable member.

Table 1: Type of Households in the Study Area

Characteristic	**Grouping**	**Percentage**	**95% Confidence Interval (CI)**	
			Lower limit	*Upper limit*
Sex of Respondent	Male	30.94	23.38	39.33
	Female	69.06	60.67	76.62
Type of Household	Male headed	62.58	53.99	70.64
	Female headed	35.97	28.01	44.54
Ethnicity	Kalenjin	43.16	34.80	51.83
	Luo	56.83	48.17	65.20

Table 2: Household Demographic Characteristics

Characteristic	**Mean**	**Std. Dev.**	**Min.**	**Max.**
HH Size	5.27	2.40	1	13
Children <5years	1.08	1.07	0	5
Elderly >60 years	0.32	0.53	0	2

In terms of educational level, 55 percent of the households have at least a member who has a primary education, while 35 percent have secondary education (Table3). Education of household members is key in making sensible economic and livelihood decisions at the household.

Table 3: Education level of most learned household member

Education Level	Percentage	95% Confidence Levels (CI)	
		Lower limit	*Upper limit*
No formal education	2.88	0.79	7.20
Primary	55.40	46.73	63.82
Secondary	35.25	27.34	43.80
Post-Secondary	6.47	3.00	11.94

4.2 Local farming technologies and practices prior to PAR project

4.2.1 Land, Water and Soil Management

According to the project baseline data, about 26 percent households had adopted a combination of at least 2 or more of the following soil management/conservation practices, namely: - stopped burning for land clearing; introduced crop cover; introduced ridges or bunds; introduced mulching; introduced terraces; introduced stone lines; introduced contour plough; introduced crop rotation; used fertilizer, manure and /or compost.

The study also investigated the prior water management technologies and practices as a means of adapting to climate change impacts by households in the project area before the PAR project initiation. The baseline data suggests that 18 percent of the households had adopted at least one of the following water management and conservation practices, namely: - introduction of small-scale irrigation where it was not existent, introduction of micro-catchments, improving the already existing irrigation technology on the farm, and improved drainage. In terms of alternative water sources for agricultural production during dry seasons, 59 percent households reported total lack of water source for agriculture, and did not have the available technology for harvesting water during rainy seasons.

4.2.2 Crop husbandry

The study investigated the farming practices and technologies towards climate change adaption prior to the PAR project inception. The baseline suggests that some households had already adapted to climate change by implementing some recommendable farming practices and technologies such as: - planting of improved varieties (32% HH), intercropping (34% HH), terraces (13% HH) and crop rotation (32% HH) as well as fertilizer use (8% HH) (Table 4).

Table 4: Farming technologies and practices prior to the PAR project in Nyando

Tech./Practice	% HH	Confidence Interval (95% CI)	
		Lower limit	*Upper limit*
Planting improved variety	32.37	24.69	40.83
Intercropping	33.81	26.01	42.32
Terraces	9.35	5.07	15.46
Crop rotation	32.37	24.69	40.83
Fertilizer	7.91	4.02	13.72

Besides, the PAR baseline also pointed out that about 83 percent of the households in the project area were applying a combination of at least three or more farming practices in order to adapt to the continuously changing climate challenges. These being the use of pesticides on crops; early planting for crops requiring longer rains; late planting for crops that require sufficient moisture content; early land preparation; integrated crop management and integrated pest management.

4.2.3 Livestock Rearing

Subsistence livestock rearing is part of livelihood sources of the households in lower Nyando. The baseline findings indicate that less than 30 percent households had adopted at least one of the following livestock management practices, namely: - stall keeping, fencing, cut and carry feeding among others. About half of the households with livestock had also introduced other livestock types and breeds that they felt were more suitable in withstanding the challenging climatic conditions. In terms of livestock feed technologies/practices, the baseline findings suggest that only about 22 percent households practiced at least one of the following: - planting of fodder crops, improving of pastures on farm, and practicing of fodder storage.

Table 4: Livestock Management Systems Prior PAR

Livestock Tech./Practice	% HH	Confidence Interval (95% CI)	
		Lower limit	*Upper limit*
Stall keeping, fencing, cut and carry feeding systems	30.23	26.36	33.84
Introduced new breeds	50.20	46.09	54.24
Fodder planting and storage, improved pastures	22.40	18.75	25.53

4.2.4 Tree/Agro forestry management

The baseline suggests that about 90 percent households were planting fruit and non-fruit trees and/or were conserving existing trees on farm. This finding suggests that agro forestry and tree planting were already traditional practices among the farmers, and thereby pointing to the fact that the PAR project would then simply build on this existing practice and for further expansion and promotion.

Table 5: Agroforestry/Tree Planting Prior to PAR

Tree/Agroforestry	**% HH**	**Confidence Interval (95% CI)**	
		Lower limit	*Upper limit*
Planting of fruit/non-fruit trees	90.20	87.32	92.28
Conserving trees on farm	89.60	86.95	91.99

4.2.5 Access to Agricultural Information

It was also investigated whether households receive information on weather related scenario. The baseline findings point out that about 83 percent households in the project area received information on extreme weather events. These households mainly accessed such information through the radio, friends/relatives/neighbors, and through personal observations. Despite the access to such information, households were mainly constrained in applying the right technology due to economic limitations.

Table 6: Access to weather information

The percent of households who had access to weather information was high at 82.8% with a 95% confidence level of 79.57% and 85.77% for lower and upper limits respectively.

4.3 Farming Practices and Technologies introduced by the PAR initiative

4.3.1 What CCAFS introduced in the PAR

A consultative key informant interview and desk review on the CCAFS activities in the area demonstrates that it established climate-smart village (CSV) model in 2012 which focuses on improving local knowledge of climate risks and variability in seasonal rainfall, dry spells, and diseases and pests to inform farming decisions. An earlier study by Atakos (2015) documented similar findings. KIIs with CCAFS staff also suggests that, it tested a portfolio of climate-smart agriculture interventions, allowing farmers to make progressive changes to crop and cropping patterns, and introduction of resilient livestock breeds. In the PAR partnership, it was found that researchers learn from farmers as they test these portfolios of promising climate change adaptation, mitigation, and risk management interventions. A study report by Schubert and Atakos (2013) confirms similar finding, where it is stated that the CSVs became innovative hubs where farmers took the lead to improve existing practices and adopt new ones, and thereby adapted to the changing climate along the way.

4.3.2 Soil, Water and Land Management

KIIs revealed that in Nyando, the PAR project is implementing soil and water management interventions for enhanced soil health. These soil and land management practices are built around existing indigenous practices and knowledge of the people in order to maximize benefits to climate change adaptation. Conservation agriculture combining zero tillage, retention of crop residues in fields and regular fallow periods has also been promoted by the project in Nyando. In a similar study by Dinesh & Vermeulen (2016), it is believed that conservation agriculture is particularly useful in regions where climates are projected to become drier, or extreme rainfall events more frequent. In line with this assertion, the PAR introduced the technologies and practices for soil, water and land management pertinent to tackling climate change challenges in Nyando Sub-County.

Additionally, it was found that CCAFS in partnership with county government agricultural extension service providers are implementing integrated soil fertility management (ISFM) as one of the key initiatives. Under the ISFM, farmers are taught how to use appropriate amounts of organic and inorganic fertilizers together with well-adapted, disease- and pest-resistant germplasm, and adoption of good agronomic practices for sustainable use of the soil. These were introduced in order to tackle the evident degraded land, declining land size and seasonal rainfall variability experienced in Nyando sub-county. Demonstration sites have been established, especially with youth groups, and in partnership with private sector and government extension agencies in advancing local adaptation actions. It was found that the project links farmers to credit providers and agro-dealers in order to access the recommended seed germ plasm and other required inputs. The PAR team is working closely with the county government on modalities of scaling out the climate smart farm technologies.

For example, it was observed that the Obinju youth group are testing smart farm concept such as practice of greenhouse farming, combined drip irrigation with the advantage of saving water. These are tried with the farmers in order to maximize use of water for agricultural production.

The study assessed that CCAFS is working with the county department of Agriculture, Livestock, and Fisheries on sustainable land management, crop husbandry and seed systems, post-harvest processing, soil and water conservation. Additionally, extension support on livestock fodder development and capacity building on improved livestock management are among the initiatives currently ongoing in the partnership.

Additionally, it was discovered that CCAFS and partners have been training farmers in creating micro-catchment water reservoirs on their farms. Water pans reinforced by dam liners (plastic sheets) have also been introduced and demonstrated in some CSVs in order to capture surface run off. By using manual foot pump, farmers are expected to irrigate their crops and provide water for their animals for up to 2-4 months after the end of the rain season. It was also found that champion farmers in the CSVs have established terraces to control soil and water movement on their farms.

4.3.3 Crop Management

Interviews with key informants reveals that farmers have been introduced to crop innovations such as breeding of more resilient crop varieties (e.g. climate resistant maize varieties), crop diversification and intensification of cropping rates. Discussions with project officers estimated that these improved varieties are now yielding up to 25-30 percent better than the ordinary maize varieties in the market under both stress and optimal growing conditions. This yield estimate closely tallies with Dinesh & Vermeulen's (2016) research findings for the same maize variety. KIIs with project staff as well as review of project reports reveals that disease- and pest-resistant germplasm are being promoted among the CSV farmers in order to enhance household food security and resilience among the households. On the other hand, intercropping is being promoted among the farmers as its yields are estimated to be higher by 50 percent than yields achieved through mono cropping.

Estimates from KIIs and FGSs suggests that about 75 percent of farmers are now proactively taking the CCAFS recommended crop varieties. Promotion of farming diversification is built on the precept that it helps the farmer improve farm incomes and reduce vulnerability to climate change.

4.3.4 Livestock Management

Desk review and interviews with project staff reveals that, since 2011 CCAFS/ILRI and other partners have been crossbreeding for heat-, drought-, and disease- resistant species of native sheep and goats that have been introduced to the CSVs. For example, the cross breeds of Galla goats have been distributed to farmers to meet food security and income needs of the households in Nyando Sub-County. These goats are believed to mature and reach market weight faster than the indigenous East African goats.

It was also identified that CCAFS/ILRI and partners are promoting improved and/or modified livestock management practices across the CSVs in Nyando. For example, improved grazing management, improved pastures with agroforestry, use of available feeds and feed technology, and the use of nutritious diet supplements and concentrates as practices emphasized by the PAR project for improved climate resilience. Other practices like cut and carry have also been introduced and promoted for adoption among the farmers. The PAR. is pursuing animal health management services and surveillance of livestock diseases with partners in the project area. Besides, appropriate manure management for improvement of soil organic matter and water-holding properties was another participatory practice the project has and is still implementing among the farming households. It is claimed the advantage of mixed farming is that the manure can be used to increase soil productivity for food production and fodder growing for livestock.

4.3.5 Agroforestry and Tree Planting

KII and review of PAR partnership contract documents reveals that community-based organizations in the project area have partnered with CCAFS, World Agroforestry Center (ICRAF), CARE International, World Neighbors, VI-Agroforestry, Kenya Agricultural Research Institute (KARI), Ministry of Agriculture, Livestock and Fisheries (MALF), and Ministry of Environment, and Natural Resources (MENR) to increase tree cover on farm. Under the partnership tree, nurseries are raised and community members then access these seedlings for planting. A mix of variety of trees have been recommended among the farmers for soil fertility improvement, family nutrition and income, as well as for fodder and fuel wood. It is believed that the farmer is able to keep the soil healthy and earn income from selling different products.

In terms of agro-forestry, KII with project staff revealed that the project raised tree nurseries and community members were allowed to access seedlings in order to plant. A mix of tree varieties are recommended for soil fertility improvement, family food/nutrition and as well as for income. Some are also promoted as fodder for livestock and for fuel wood.

4.3.6 Climate Information Services

Climate Information Services is essential in farmer's decision-making and especially due to uncertainty due to climate variability and change. It is established that CCAFS works with partners (e.g. Maseno University, University of Reading, and Kenya Meteorological Services) in testing models for developing and delivering seasonal forecast and climate services and information. This includes the use of information communication technologies (ICTs) to improve decision making in agriculture. Through local organizations, seasonal forecasts are disseminated via mobile telephone, together with agro advisories to enable farmers in the project area to know when and what to plant.

In this study, rainfall data from Kisumu Meteorological Station for 54 years were used. Start of rains was summarized over the period as shown in Table 7. The start of rains was limited to within 30 days of March since such late starts would stress the plants since they had seeds that would grow for three to four months. Late planting would not optimize the yields. Table 7 gives the start, end and hence the season length for Kisumu. The definitions for start of rains and the end of rains are as defined:

Start of rains *defined as the first instance in after March 1st or October 1st where at least 20mm of rain was recorded over a period of three days. The two months are the beginning of the long and short rains respectively.*

In case the event of end of rain was not met, that is, there was more than 40 mm of rain water in soil even till the start of the next season, the end was forced to end on the 90th day.

Using information from table 7 below several risks are calculated. The formula and the values are calculated in the table below.

$$\text{Risk of rain failing to start} = \frac{\text{\# Seasons that did not start}}{\text{Total Number of seasons}}$$

$$\text{Risk of inadequate rain (<400mm)} = \frac{\text{\# Seasons with rain} < 400\text{ mm}}{\text{Total number of seasons}}$$

$$\text{Return period} = \frac{1 \times 10}{\text{Risk}}$$

Table 7: Seasonal events of start and end of rains for the long and short rains in Kisumu

	Long Rains (MAM)				***Short Rains (OND)***			
Year	Start	End	Season Length	Total Rain (mm)	Start	End	Season Length	Total Rain (mm)
1961	61	180	119	560.8	287	377	90	793.3
1962	70	160	90	781.5	288	378	90	272.3
1963	62	253	191	850.9	280	329	49	178
1964	62	243	181	864.7	295	385	90	215.9
1965	75	165	90	683.1	287	302	15	119.8
1966	62	216	154	683.4	284	374	90	102.8
1967	85	123	38	234.5	275	365	90	483
1968	62	268	206	1006.5	285	375	90	543.1
1969	78	173	95	414.1	282	372	90	293.8
1970	67	177	110	569	283	373	90	285.5
1971	69	159	90	721.6	276	295	19	107.3
1972	73	204	131	611	275	308	33	151.1
1973	0	0	0	0		0	0	0
1974	61	219	158	761.5	276	334	58	168.3
1975	64	66	2	47.7	277	350	73	238.3
1976	88	99	11	91.7	277	281	4	51.9
1977	66	71	5	69	292	299	7	82.9
1978	61	287	226	1057.8	275	287	12	14.8
1979	70	192	122	600.7		0	0	0
1980	61	65	4	64.1	287	377	90	210.7
1981	75	205	130	694.6	275	334	59	86.8
1982	80	183	103	412.8	284	374	90	561.1
1983	74	187	113	497.9	278	345	67	325.3
1984	0	0	0	0	275	323	48	163.9
1985	81	268	187	973.1	293	383	90	141.3
1986	65	218	153	814.4	298	388	90	231
1987	66	95	29	170.9	282	307	25	169.7
1988	64	207	143	749.6	278	337	59	190.2
1989	68	187	119	619	280	297	17	126.7
1990	61	162	101	477.1	275	350	75	192.1
1991	71	161	90	671.7	284	320	36	221.1
1992	78	112	34	172.8	277	367	90	248.7
1993	78	168	90	597.8	288	378	90	176.9
1994	63	268	205	1059.4	295	364	69	352.1
1995	70	160	90	604.8	282	338	56	321.2
1996	61	77	16	106.3	275	361	86	316.9
1997	83	199	116	620.4	287	303	16	123.5
1998	66	320	254	933	275	320	45	179.6
1999	61	151	90	673.9	282	347	65	246.8
2000	65	124	59	255.8	293	383	90	366.3
2001	72	138	66	291.3	281	347	66	237.4
2002	61	232	171	897.7	286	338	52	261.7
2003	81	196	115	614.6	303	348	45	168.9
2004	71	161	90	431.9	275	365	90	343.7
2005	61	78	17	91.7	293	383	90	165.2
2006	67	93	26	158.9	275	311	36	126.7
2007	61	253	192	715.9		0	0	0
2008	73	98	25	169.2	275	357	82	378.4
2009	61	173	112	494.7	281	371	90	350.9
2010	61	72	11	50.2	285	286	1	13.2
2011	75	97	22	151.4	286	376	90	85
2012	61	185	124	594.5	278	322	44	96.6
2013	68	186	118	598.9	282	326	44	181.5
2014	71	161	90	396.3		0	0	0

Table 8: Risks involved in the onset, length, and amount of rain for Kisumu

Risk	***Long Rains***	***Short Rains***
Rain failing to start	$\text{Risk of rain failing to start} = \frac{\text{\# Seasons that did not start}}{\text{Total Number of seasons}}$	$\frac{4}{54} \times 10 = 0.7$
Short season (< 60 days)	$\frac{16}{54} \times 10 = 3$	$\frac{27}{54} \times 10 = 5$
Inadequate rain	$\frac{18}{54} \times 10 = 3.3$	$\frac{50}{54} \times 10 = 9.3$

Return period for start of rains

The risk of the season failing to start was always less than one season in ten years. The value 0.4 for the long rains can be translated to a return period of 25 years (long rains seasons). That is, the long rains failed to start once in 25 years. The return period for the short rains was 14.28 years (short rains seasons). That is, the short rains failed to start once in 14 years.

$$\text{Return period for rail of start of Rain (MAM)} = \frac{1 \times 10}{0.4} = 25$$

$$\text{Return period for rail of start of Rain (OND)} = \frac{1 \times 10}{0.7} = 14.28$$

Return period for duration of the season

The risks were higher for the length of the season. The variety of maize crop grown in the region grows for three months. The risk for optimal growth was calculated using the formula given, and it is tabulated in table 8.

The risk of three in ten years translates to a return period of 3.3. That is, for the long rains (MAM), the season would be short once in every three years. The return period for the short rains, (OND) was two. That is, once in two seasons, the long rains would be too short to use for growing the maize variety.

Total seasonal rainfall

As shown in table 8, the risk of having rainfall below 400 mm in the long rains was one three times in ten years. A return period of 3.3 year.

However, there was more stress on the maize variety for the short rains (**OND**). Nine in ten years did not have enough moisture for optimal yield for the crop.

4.4 Adaptation of PAR Climate Change Technologies & Practices by farmers in Nyando

4.4.2 Soil, Water and Land Management

Household interviews with farmers in the study area revealed that conservation agriculture started taking place among the farmers such as zero tillage, retention of crop residues in fields and regular fallow periods, although uptake levels are still below 50 percent of total household population in the CSVs (Table 9). Among the most adopted practices is use of organic and inorganic fertilizers where about 47 percent of the households are actively enriching soil fertility in order to improve crop productivity. It was found that the proportion of households using terraces did not significantly change from the baseline study.

Qualitative observations revealed that farmer groups are adjusting to practices of water conservation in order to maximize the use of available water for crop production. For example, the Obinju youth group who are now testing smart farm concept of greenhouse farming, combined with drip irrigation. Physical checks have shown that these farmer groups are practicing micro-catchment water reservoirs where water pans are used for conserving surface water, and manual foot pumps are used for irrigating their crops and provision of water for livestock.

Table 9: Land use and management information

Crop production practices adopted among farmers	Proportion of HHs in CSVs who have adopted	Confidence Interval (95% CI)	
		Lower limit	Upper limit
Expanded area	22.80	18.59	27.46
Introduced intercropping	36.81	31.81	42.00
Introduced crop cover	25.27	20.89	30.07
Introduced mulching	19.51	15.56	23.96
Introduced terraces	17.58	13.81	21.89
Introduced contour ploughing	16.48	12.82	20.70
Started using manure or fertilizers	46.70	41.49	51.97

4.4.3 Crop Management

Farmers in the project area have progressively moved to adaptive strategies such as crop-cover; inter cropping, expanding agriculture land area among others. Although uptake rates are still low among the farmers, the study found that about 32 percent of the farmers either introduced new crops or are testing new crops on farm (Table 10). Similar proportion of households also stopped growing some crops due to failure to adapt to the challenging climate conditions. About

34 percent of households were found to practice early planting as a way of maximizing the use of moisture during the short rains (Table 10). Reviewed reports elsewhere by other studies reveal similar trends, for example in Deressa et al. (2009) it was found that farmers in the Ethiopian highlands are growing different crop varieties, practicing tree planting, soil conservation, early and late planting, and irrigation all with the aim of trying to adapt to the changing climatic conditions. In a study by Seo & Mendelsohn (2008), it is stated that farmers adapt to climate change by changing crops from the traditional crops.

Table 10: Cropping Technologies and Practices among farmers

Practice/Technology	Prop. of HHs	95% CI	
Introduced/tested new crops	32.42	27.63	37.49
Stopped growing a crop totally	30.22	25.54	35.22
Use fertilizer/manure/compost	31.87	27.11	36.93
Use pesticide/Herbicide	13.46	10.13	17.40
Practicing early planting	34.07	29.21	39.19

Focus group discussions with farmers revealed that farmers have especially embraced the breeding of more resilient maize varieties that have shown exceptional ability to give yields despite the climate challenges. Disease - and pest - resistant germplasms been introduced by CCAFS have also been welcomed by communities, and are actively switching to such varieties as opposed to the traditional ones. Group interviews with farmers also suggests that crop diversification has been accepted and adopted by farmers in the area.

4.4.4 Livestock Management

The farmers in these CSVs have variedly adopted the introduced livestock technologies and practices in the project area. Although the proportionate adoption are still low, it was found that certain practices have taken root among the farmers. For example, the study found that 38 percent have increased their herd size especially for small ruminants (shoats) and poultry, while others have adjusted to climate change by reducing the size of their herd (30 percent), especially cattle owners (Table 11). 23 percent of households had also introduced new breeds in the previous year to replace the existing breeds that had poor adaptation to the harsh climatic conditions these include; Gala goats and Red Maasai sheep. About 17 percent of households also introduced completely new type of animals i.e. goats, sheep, poultry etc. to their herd that they did not have before.

In terms of livestock management practices, it was found that some households (17 percent) are practicing fencing of livestock area, cut and carry, growing of fodder/nappier on farm among others in the study area (Table 11).

Table 11: Livestock Changes in Previous Season

Changes	Proportion of HHs	Prop. confidence level (95% CI)	
		Lower limit	*Upper limit*
New farm animal type	17.27	13.50	21.59
Tested new animal type	6.13	3.88	9.13
Stopped keeping some type	14.48	11.01	18.56
New breed introduced	22.56	18.34	27.24
Reduced herd size	30.64	25.91	35.69
Increased herd size	38.16	33.11	43.41
Changed herd composition	15.04	11.51	19.17
Stall keeping	7.52	5.01	10.75
Fencing	16.99	13.25	21.28
Cut and carry	17.55	13.76	21.89
Growing fodder	15.32	11.75	19.47

Interviews with farmers suggested that households were moving to livestock types that were more productive, drought tolerant, and disease resistant species; and avoiding those that are prone to emerging diseases e.g. the Gala goats (Table 12).

Table 72: Reason for Making Livestock Changes

Changes	Proportion of HHs	Prop. Confidence level (95% CI)	
		Lower limit	*Upper limit*
Better price	30.49	25.80	35.51
Market demand	31.59	26.85	36.64
Better yield	53.57	48.30	58.78
Drought tolerance	11.26	08.21	14.97
Disease resistance	16.21	12.57	20.40

4.4.5 Agro-forestry and Tree Planting

The study found that 90 percent of HH were growing trees and other horticultural plants on their farm. This figure has appreciated upwards since the baseline (86%). Focus group discussions with farmers suggested that households with agro-forestry and trees had better advantage as they reared animals and integrated with crop production that mutually benefit from each other (Table 13).

Table 83: Tree products used by households

Products	Proportion of HHs	95% CI	
		Lower limit	*Upper limit*
Timber	71.43	66.49	76.02
Poles	38.46	33.44	43.67
Fuel wood	18.96	15.06	23.37
Charcoal	6.87	4.49	9.97
Manure/Compost	1.92	0.78	3.92
Overall agro-forestry and tree planting on farm	90.32	86.48	92.86

4.4.6 Climate Information Services

The study identified that 98 percent of farmers had received climate information on a timely basis, either by phone, radio or by word of mouth, to support their decision making during production (Table 14). FGDs with the farmers revealed that the PAR partnership had strongly contributed to this information access on climate and weather conditions. Besides, it was also claimed that the face-to-face meetings with local agriculture extension agents complemented the radio messages and discussed implications of these forecasts with the farmers for accurate interpretation and practical action. There was therefore a significant increase in access to climate information by the households in Nyando since the baseline (2011).

Table 14: Access to climate information and weather forecasts

Products	Proportion of HHs	Prop. confidence level (95% CI)	
		Lower limit	*Upper limit*
Access to climate information	98.40	96.96	99.20

4.5 Food Security and Livelihood Outcomes

4.5.1 Income Sources

The study assessed the main sources of cash for the households, and it was found that more than half of the households obtained income from small-scale business enterprises (57 percent) and innovation funds (53 percent) (Table 15). On the other hand, households also received income from wage employment elsewhere but mainly from agricultural labour (36% HH) (Table 15). It was also observed that the sale of livestock and crops is another source of household income, although existent among a fewer proportion of households (25%). In terms of whether income expansion and asset creation opportunities are existent, especially through micro-finance and other loan schemes, it was found that there is limited access to credit among the farmers (14%HH).

Table 95: Household sources of income

Source	Proportion of HHs	95% CI	
Innovation funds	52.75	47.47	57.97
Hired labour	35.71	30.79	40.87
Business	57.42	52.16	62.56
Employment	10.44	7.49	14.05
Loans	13.74	10.37	17.71
Rental income	4.67	2.74	7.37
Sale of crop and livestock	25.38	20.16	27.10

4.5.2 Household months of food inadequacy

The study investigated food availability to households during the lean months (March – June) when food is usually less plentiful due to annual seasonal fluctuations experienced in Lower Nyando. It was observed that majority of households rely mainly on off-farm foods, acquired through purchases and other means during these lean months (Table 16), while only about 14% utilized their own-farm produced foods. Therefore there has been a significant increase in the number of households having access to own-foods (14%HH) during the worst month of the lean season than were observed at the time of the baseline (5%HH) (p-value <0.05).

Qualitative discussion with farmers groups indicates that since the introduction of the CSVs, households in the area have generally improved their household food security conditions as compared to the periods before the project. Access to micro-credit schemes has also enhanced agricultural potentials, and as such, farmers have increased their overall food outputs and subsequent income opportunities through sale of surplus stock.

Table 106: Household source of food

Month	**Main Food Source**	**Prop. HHs (%)**	**Confidence interval (95%)**	
			Lower limit	*Upper limit*
March	Own farm	21.45	17.31	26.06
	Off farm	78.55	73.94	82.69
April	Own farm	15.04	11.51	19.17
	Off farm	84.96	80.83	88.49
May	Own farm	13.65	10.27	17.64
	Off farm	86.07	82.05	89.48
June	Own farm	37.33	32.31	42.56
	Off farm	62.40	57.16	67.42
July	Own farm	86.91	82.97	90.22
	Off farm	13.09	9.78	17.03
August	Own farm	94.15	91.20	96.34
	Off farm	5.85	3.66	8.80

Chapter Five

5.0 Summary of Findings, Conclusion and Recommendations

5.1 Introduction

Climate change effects have been globally and significantly felt in recent years. CCAFS and partners are implementing a participatory action research among the farmers in Nyando, integrating a science approach based on a climate-smart village (CSV) model, focused on improving local knowledge of climate risks and variability in seasonal rainfall, dry spells, diseases and pests, aimed at informing farming decisions. The goal is to respond to climate variability, improve food security, and enhance household incomes. Identification of resilient technologies, training of farmers to change local practices, and improving planning for adaptation to changing farming conditions are among the key priorities. The CSVs act as innovative hubs where farmers take the lead to improve existing practices and adopt new ones. CCAFS conducts annual monitoring of changes to crop production, livestock, land/soil and water management, agro forestry as well as climate information. As part of this monitoring exercise, this study aimed at measuring the effects of the PAR project on beneficiary households. The specific objectives of the study included: 1) To determine the existing local farming technologies and practices prior to project inception; 2) To analyse the newly introduced farming technologies and practices among households in the CSVs; 3) To assess the adoption level of the newly introduced farming technologies and practices; 4) To assess the effects of the newly introduced farming tecnologies and practices on household livelihoods. Below is a summary of the findings of this study.

5.2 Summary of Findings

5.2.1 Farming technologies and practices prior to the PAR project

In terms of Land, water and soil management, the project baseline indicates that about 26 percent of farmers had already engaged in some form of soil management and conservation practices such as crop cover, terraces, contour, crop rotation, use of fertilizers and manure among others. The baseline figures also suggested that about 18 percent of households were practicing small-scale irrigation and improved drainage on farm. In terms of access to water during dry seasons, it was found that over 50 percent (59% - to be precise) of the households lacked access to water and had supporting technologies such as water harvesting.

In terms of crop husbandry, 35 percent and below had adopted practices such as planting of improved crop varieties, intercropping, terraces, crop diversification and fertilizer use among others. The baseline information indicated that majority of households (83%) had adopted a combination of practices such as early planting, late planting, early land preparation, integrated crop management and pest management practices.

In the area of livestock husbandry, it was noticed that at least 30 percent of households in the study area had integrated livestock technologies and practices by the time of the baseline, such as stall keeping, livestock fencing, cut and carry practices and livestock feeding among others.

On the other hand, the baseline data indicates that majority of households (90%) were planting fruit and non-fruit trees, as well as conserving existing trees on farm. In terms of access to climate information, the baseline suggested that 83 percent of households had access to such climate and weather forecast information.

5.2.2 Farming Technologies and Practices introduced by PAR in Nyando

CCAFS and partners introduced climate smart innovations in Nyando in 2012. The CSV model focuses on improving local knowledge of climate risks and variability in seasonal rainfall, dry spells, and diseases and pests to inform farming decisions. Under the PAR partnership, it tested a portfolio of climate-smart agriculture interventions, allowing farmers to make progressive changes to crop and cropping patterns, and introduction of resilient livestock breeds.

In terms of soil, water, and land management intervention, the project adopted a participatory approach of soil and land management practices built around existing indigenous practices and knowledge of people in order to maximize benefits to the farmers. Practices such as zero tillage, retention of crop residues in fields, and regular fallow periods among others have been promoted. ISFM was also introduced among the farmers where appropriate use of fertilizers was recommended. Disease- & pest-resistant germplasm and adoption of good agronomic practices were introduced so that farmers can maximize returns. The PAR also linked farmers to micro-credit schemes where they can access finances for recommended soil and land management practices. Technologies such as small-scale greenhouse farming drip irrigation, surface run-off water harvesting, and micro-catchment water reservoirs were promoted in the project. Technologies such as the use of food pumps for irrigating crop fields and supply of water to livestock were introduced by the project.

On the side of crop management, crop innovations such as breeding of more resistant crop varieties were tried with the farmers. Among the outstanding varieties tried with the farmers was the climate resistant maize variety. Intercropping was also widely disseminated among the farmers by the PAR project.

In terms of livestock management, the partnership embarked on breeding of heat-, drought- and disease resistant species of native sheep and goats, e.g. Gala goat. This breed was widely promoted among the farmers in the CSVs. Besides, improved/modified livestock management practices such as improved grazing, improved pastures with agro-forestry, use of feeds and feeding technologies, supplementary feeds and concentrates were highly advocated among farmers in the project area. Management practices such as cut and carry were demonstrated in the CSVs. In terms of livestock health, the project partnership aligned animal health and diseases surveillance among its priority activities so that farmers were more aware of livestock health and had access to services. To further complement, manure management was demonstrated among the farmers for improvement of soil organic matter and water holding properties with subsequent increased soil productivity for food production and fodder growing for livestock.

The project also promoted agro-forestry and tree planting where it raised tree nurseries and provided access to seedlings for planting by the farmers. Mixed tree varieties had also been recommended and promoted for soil fertility, family food nutrition and enhance income. Other benefits such as livestock fodder and wood fuel are among the things farmers were taught as they plant trees and establish agro-forestry on farms.

In order to promote access to climate information, the project partners tested model of seasonal forecasting and provided climate information services. The use of ICT such as mobile phones was greatly emphasized for improving decision making in agriculture. These were complemented by agro advisories to farmers on what and when to plant of agricultural crops.

5.2.3 Adoption of technologies and practicies for climate change by farmers

30 percent households as compared to the baseline 26 percent have embraced conservation agriculture. Average households (47%) had adopted appropriate use of fertilizers (organic and inorganic) for enriching soil productivity as compared to the only 35 percent as at the time of project baseline. Qualitative discussions with farmers groups indicated that technologies such as greenhouse farming, drip irrigation, micro catchment water reservoirs and use of pump technologies for irrigating crop fields have been adopted by farmers' groups. Other conservation practices such as crop cover, mulching, and contour ploughing that were existent among the farmers at the time of the baseline continued to be practiced.

The study noted that a varied proportion of households (10-20 percent households) had adopted and adjusted to different practices that were introduced by the PAR, namely: introduction of new crops, stopped the growing of some crops, early planting, late planting, use of pesticides, planting of drought resistant crop varieties (e.g. maize), planting of disease- and pest-resistant germplasm and crop diversification.

In terms of livestock management, the study identified that farmers have adopted to practices such as reducing herd size, increasing herd size to more climate resistant small ruminants, introduction of new breeds on farm, and introduction of new animal types (17%). It was noted that 16 percent households had started keeping drought tolerant and disease resistant varieties. Practices such as livestock fencing, cut and carry and growing of fodder on farm are noticeable among the farmers.

The study observed that similar proportion of households were practicing tree planting, tree conservation and agro-forestry plantation as compared to the baseline (90%). As is the approach of the PAR, farmers have continued to embrace tree planting and agro-forestry, something to grasp.

In terms of access to climate information, it was confirmed that 98 percent farmers have taken up the use of mobile phones and radios in accessing climate information as compared to the baseline 83 percent. Farmers receive information on what crops to plant and when to plant in order to survive climate challenges in food production.

5.2.4 Food Security Outcomes of the PAR project in Nyando

The study found that farmers had generally improved their household food security outcomes. Qualitative discussions with farmer groups suggested that households had more secure food conditions during lean seasons unlike before. Baseline primary data had shown that only 5 percent households had own-farm food as a main source during lean seasons. However, this has proportionately appreciated to 14 percent as established by this study. Farmers had generally attributed these outcomes to the PAR initiative.

5.3 Conclusion

The study conclusions have been drawn based upon the research questions set out by this study.

i) What were the previous farming technologies among the Nyando sub-county households before the CCAFS PAR project was introduced?

Farmers in the study areas were practicing conservation agriculture although by smaller proportions (<40% HH), namely: crop cover, terraces, contour ploughing, crop rotation, use of fertilizers and manure. Practices such as small-scale irrigation and improved drainage on farm, planting of improved crop varieties, intercropping, terraces, crop diversification and fertilizer, early planting, late planting, early land preparation, integrated crop management and pest management practices were existent among the farmers. The study also identified that stall keeping, livestock fencing, cut and carry practices and livestock feeding were among the already existing indigenous management practices. In terms of agro-forestry and tree planting, majority of households (90%) were already complying with such climate change demands on farm where fruit and non-fruit trees had been planted by farmers on a small scale. Besides, 83 percent of households had access to climate and weather forecast information.

In conclusion, the PAR initiative picked from this indigenous climate smart practices among the farmers that were already existent. However, challenges such as access to water for crop irrigation and livestock use were prevalent among the farmers by the time of the baseline, where 60 percent lacked access. Although some traces of climate smart practices were existent, the extent of adoption was generally low among the households in the study area.

ii) Has PAR contributed to smallholder farmers' adoption of climate smart technologies?

It is noted that the CSV model focused on improving local knowledge of climate risks and variability in seasonal rainfall, dry spells, and diseases and pests to inform farming decisions. Besides strengthening of indigeneous climate smart knowledge among the farmers, some of the noticeable technologies and practices aimed at promoting adoption of climate smart technologies included: ISFM introduced among the farmers by the PAR, growing of disease- & pest-resistant germplasm, breeding of more resistant crop varieties tried with the farmers (e.g. Maize), promotion of small-scale greenhouse farming, drip irrigation, surface run-off water harvesting, and micro-catchment water reservoirs. In terms of livestock management, PAR on breeding of heat-, drought-, and disease resistant species of native sheep and goats, improved/modified livestock management (e.g. feeds and feeding technologies, supplementary feeds, and concentrates) were among remarkable contributions. Tree nurseries raised to provide access to seedlings by the farmers, and testing of seasonal forecasting and provision of climate information by the PAR partners are all suggested that the PAR contributed relevant technologies and practices to farmers' adaptation to climate change.

In conclusion, the PAR contributed relevant climate change adaptation technologies and practices that the farmers could learn from and adopt in order to survive in the face of the changing climate.

iii) To what extent have farmers adopted climate smart technologies and practices since PAR was introduced?

Practice of conservation agriculture had appreciated from 26 percent to 30 percent among households since the baseline. Appropriate fertilizer use has also appreciated upwards from 35 percent to 47 percent. Farmers' groups have adopted other technologies such as greenhouse farming, micro catchment water reservoirs, and use of pump technologies for irrigating crop fields, although the qualitative discussions could not verify exact proportion of adoption. Indigenous soil water conservation practices such as crop cover, ridges, furrows and mulching among others had continued to prevail among the farmers since the baseline. The use of resistant crop varieties and rearing of tolerant and disease resistant animals are starting to become preferred options among the farmers. Almost all households (98%) have begun using climate information for agricultural decision-making. Based on these trend, it can be concluded that there was a slow but steady progression into adoption of climate smart technologies and practices among the farmers.

iv) Has the adoption of climate smart technologies by farmers led to climate risk reduction, positive food security and livelihood outcomes?

In terms of household hunger months, it was observed that farmers have generally improved their household food security outcomes. Comparison data has shown that 95 percent households had no access to own-farm food during lean months at the time of the baseline, as compared to the reduced 86 percent households at the time of this study. Qualitative discussions with farmer groups suggest that households had more secure food conditions during lean seasons unlike before. These findings point to the fact that the PAR contributed to enhanced food security and livelihood conditions among the farmers as attributed by the community during qualitative interviews.

5.4 Recommendations

The adoption of climate smart technologies and practices is not an option but the only choice in the face of the escalating climate threats to agricultural livelihoods. It is strongly recommended that farmers in the region and elsewhere in Kenya continue to be sensitized and assisted in adjusting to climate change adaptation as its impacts are becoming real.

Owing to the findings of this study, it is recommended that CCAFS and partners continue to strengthen the adoption of climate smart technologies and practices among the farming communities in Nyando sub-county since uptake levels have still not reached significant levels.

Currently embraced technologies with sure benefits should be expanded from within the CSVs so that the PAR can register greater impact.

5.5 Suggestion for Further Studies

Future studies should focus on the quantification of climate change adaptation benefits by using control groups where PAR activities and those of related partners have not been significant. This will lead to solid attribution claims of changes in food security and livelihoods as impacts of the PAR.

Other than measurement of hunger months as a measure of food security, future studies could explore other food security and livelihood measures in order to further understand the contribution of the PAR.

Studies on sustainability of such PAR initiatives could be investigated in future studies, given that much support has been coming from development partners than from local or national governments.

Study on policy gaps for the success of future similar interventions would greatly address the impediments that are still salient, yet PAR has demonstrated relevant contribution to assisting farmers in the face of changing climate conditions.

Further studies on the cost of effective adaptation technologies and whether farmers can afford these technologies e.g. fertilizers, improved seeds, irrigation technologies etc. needs to be conducted so that durable solutions can be identified.

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Appendices

Appendix i: Survey Questionnaire

CCAFS PAR Monitoring Questionnaire

Site ID (SITEID)				
Household ID (HHID)				

	(**LR**=long rains) (**SR**=Short rains)	**Year** (2013, 2015 etc.)
Season		

Introduction and consent by main respondent

Before the beginning of the interview read out the following paragraph and ensure that the respondent understands before asking for consent.

"Good morning/afternoon. We are coming from (_partner organization's name_) __ with permission from the local government. We are conducting a monitoring survey **looking at farming practices and how they change over from last season after the PAR activities**. We would like to ask you some questions that should take no more than one to one and half hours of your time. We would like to share some of this information widely in order that more people understand how food is grown and used in this region and the issues that you face regarding food production and soil, water and land management.

Your name will not appear in any data that is made publicly available. The information you provide will be used purely for research purposes; your answers will not affect any benefits or subsidies you may receive now or in the future. Do you consent to be part of this study? You may withdraw from the study at any time and if there are questions that you would prefer not to answer then we respect your right not to answer them.

Has consent been given? ***(01=Yes, 00=No)*** [__ __] CONSENT

Section 0 – Data Handlers

	Name ✍	Code	Date (dd/mm/yyyy)	Signature
Interviewer	____________	[__ __] FLDCODE	__ __ / __ __ / __ __ __ __ FLDDAY, FLDMTH,FLDYEAR	____________
Supervisor	____________	[__ __] SUPCODE	__ __ / __ __ / __ __ __ __ SUPDAY,SUPMTH,SUPYEAR	____________
1st Data entry clerk	____________	[__ __] DE1CODE	__ __ / __ __ / __ __ __ __ DE1DAY, DE1MTH,DE1YEAR	____________
2nd Data entry clerk	____________	[__ __] DE2CODE	__ __ / __ __ / __ __ __ __ DE2DAY, DE2MTH,DE2YEAR	____________

Interviewer codes
(01=
02=
03=
04=
Supervisor codes
(01=Philip Kimeli

Section I: - Household Respondent and Type

Ideal respondent: household head and/or spouse. Most of these questions can be completed without having to question the respondent directly. Be sensitive about the way you gather this information.

1. Name of household head	HEADNAM1	
a. First name (more than 1 if needed)		✎________________________
b. Last name	HEADNAM2	✎________________________
2. Name of Main respondent		
a. First name (more than 1 if needed)	RESPNA 1	✎________________________
b. Last name	RESPNA 2	✎________________________
3. Sex of the respondent *(01=Male, 02=Female)*	RESPSEX	[__ __]
4. What is the relationship of main respondent to household head *(00=Head, 05=Nephew/Niece,* *01=Spouse, 06=Son/daughter-in-law,* *02=Parent, 07=Brother/sister,* *03=Child, 96= Other related (specify)* *04=Grandchild, 97=Other unrelated (specify)*	RESPREL	[__ __]
	SPECREL	✎_____________________
5. Household community/ethnicity/caste ***(see code sheet)***	HHETHNC	[__ __]
6. Household type *01=Male headed, with a wife or wives,* *02=Male headed, divorced, single or widowed,* *03=Female headed, divorced, single or widowed,* *04=Female headed, husband away, husband makes most household/agricultural decisions,* *05=Female headed, husband away, wife makes most household/agricultural decisions,* *06=Child headed (age 16 or under)/Orphan* *96=Other, specify*	HHTYPE	[__ __]
	SPECTYPE	✎_____________________
7. Household category *(01=Baseline, 02=Non-Baseline)*	HHCATGR	✎_____________________

Section II: - Demography

1. How many people, including yourself are in your household?	HHSIZE	[__ __]
2. How many people in your household are under the age of 5yrs?	HHLT5	[__ __]
3. How many people in your household are over the age of 60yrs?	HHGT60	[__ __]
4. What is the highest level of education obtained by any household member?	HHEDUC	[__ __]

00=No formal education,01=Primary, 02=Secondary, 03=Post-Secondary

Section III: - Sources of Livelihood Security

Read the following question as an introduction to the questioning. Once in the table, go row by row.

1. During ***last season***, which of the following did you produce **from your own farm,** and how were they used?
Note: This only refers to production and use of products from the farm. If, for example, firewood is collected off-farm and used or sold, then it is not included

a. Crop production

CROP PRODUCT	*Code*	*Any produced / harvested on your own farm? **(00=No, 01=Yes)***	*If yes, which crop? (**see crop codes**)*	*What size of land is under the crop in acres*	*Who does most of the work? **(See codes)***	*Type of seeds used **(00=non-improved, 01= Improved, 02=Both)***	*Seed use*			*Did you use any fertilizer **(00=No, 01=Yes)***	*Fertilizer use*				*Did you use any pesticides? **(00=No, 01=Yes)***	*If yes, what was the source?(**see codes**)*	*Harvest details*		*Harvest use details*			
																			consumption		*Sales*	
			CRPTYP	***ACRES***	***RESP***		***UNIT Use codes***	***QNTY***	***SOURCE Use codes***		***FERTYPE Use codes***	***UNIT Use codes***	***QNTY***	***SOURCE Use codes***		***SOURCE Use codes***	***UNIT Use codes***	***QNTY***	***UNIT Use codes***	***QNTY***	***UNIT Use codes***	***QNTY***
Food crop	FCRP1																					
Food crop	FCRP2																					
Food crop	FCRP3																					
Food crop	FCRP4																					
Food crop	FCRP5																					
Food crop	FCRP6																					
Food crop	FCRP7																					
Cash crop	CCRP1																					
Cash crop	CCRP2																					
Cash crop	CCRP3																					
Fruit	FRUT1																					
Fruit	FRUIT 2																					
Fruit	FRUIT 3																					
Fruit	FRUIT 4																					
Vegetable	VEGT 1																					
Vegetable	VEGT 2																					
Vegetable	VEGT 3																					
Vegetable	VEGT 4																					
Others	OTHR																					

NB: Make notes below on the estimated time the produce is expected to last.

b. Livestock production

I would like you to tell me about your livestock

Livestock type	code	*Do you own any? **(01=Yes, 00=No)***	*Who is responsible **(see codes) RESP***	*How many owned before start of the PAR interventions (**Feb 2012**)*	*How many owned now*	*No. Sold since the start of the PAR interventions (Feb 2012)*	*No. Born since start of the PAR interventions (Feb 2012)*	*No. Slaughtered since the start of the PAR interventions (Feb 2012)*	*No. Lost/died/stolen since the start of the PAR interventions (Feb 2012)*	*Product obtained details*			*Consumption details*		*Sales details*	
										Product See codes	***Unit see codes***	***Qnty***	***Unit See codes***	***Qnty***	***Unit See codes***	***Qnty***
Cattle	CTL															
Sheep	SHP			;												
Goats	GOAT															
Chickens	CHCK															
Bee hives	BEHV															
Donkeys	DNK															
Rabbit	RBT															
Duck	DCK															
Other (Specify)	OTH															

Note: products obtained; cattle & goats ask for milk and units in litres and how much revenue generated, for chicken ask for eggs and bee hives ask for honey

c. Tree and Other products produced/consumed on farm

Other products	**code**	*Do you produce/harvest any? (**01=Yes 00=No**)*	*Quantity and Unit of production (**see codes**)*		*Who is responsible (**see codes**) RESP*	*Consumption*		*Sales*	
			Unit	*Quantity*		*Unit*	*Quantity*	*Unit*	*Quantity*
Timber	TIMB								
Poles	POLES								
Fuel wood	WOOD								
Charcoal	CHAR								
Manure/compost	COMP								
Others (specify)	OTHRS								

Read the following question as an introduction to the questioning. Once in the table, go row by row.

2. During **last season**, did you receive any cash through any of the following means? ***Note: If answer to 1 is 'yes' then ask 2, 3&4, otherwise ask 5***

Source of cash	**code**	*1. Any cash income during last season.* ***If Yes, go to 2&3*** ***If No, go to 4***	*2. If Yes, was this a new source, which you did not have previously?*	*3. What were the main uses of the income?(**List up to three uses**)*	*4. What were the percentage proportions of the income allocated to each use in **(3)***	*4. If No, did you receive cash from this source at any time in the past?*
		CASH ***(01=Yes, 00=No)***	THIS ***(01=Yes, 00=No, -8=N/A)***	***USE (See codes)***		LAST ***(01=Yes, 00=No, -8=N/A)***
Innovation funds (CBO/Loan from groups)	INVF			1 2 3	1 2 3	
Farm labour	FRML			1 2 3	1 2 3	
Business (other than farm products)	BUSN			1 2 3	1 2 3	
Employment or other payment from projects/ government including benefits in kind (e.g. Salary, pensions, aid, subsidies, etc.)Other paid employment	OTHPE			1 2 3	1 2 3	
Payments for environmental services (PES)	ENVS			1 2 3	1 2 3	
Renting out your own land	RENT			1 2 3	1 2 3	
Loan/credit from a bank or other formal institution (microfinance, projects/programs, registered group)	LNBK			1 2 3	1 2 3	
Other source (specify)	OTHR			1 2 3	1 2 3	

Section IV: - Crop and Livestock Changes

Read the following question as an introduction to the questioning.

a). I would now like you to tell me what **changes** you have made in the way you have been managing your crops over the last season (start of the long rains, 2012).

1. Have you or your family been farming in this locality in the **previous** seasons? ***(01=Yes, 00=No)*** FARMPRVSN [__ __]

Have you …	Code	*Response* *(00=No, 01=Yes)*	**Write the crop codes (use the code sheet)** *If **yes**, to which crops?* *CRP1*	*CRP2*	*CRP3*	*CRP4*	*CRP5*	*CRP6*	*CRP7*
Introduced any new crop?(since previous season) ***(see crop codes)***	CRIN								
Have you tested any new crop (still not sure about) ***(see crop codes)***	CRTS								
Stopped growing a crop (**totally**) ***(see crop codes)***	SGCT								
Stopped growing a crop (since previous season) ***(see crop codes)***	SGC1								
Other, specify									

2. What were your three most important crops **last season**? By 'main crop', I mean the crops you grow on your farm, which are most important to your household's livelihood. ***(see crop codes)***	MNCRPNW1	[__ __]
	MNCRPNW2	[__ __]
	MNCRPNW3	[__ __]

Read the following question as an introduction to the questioning.

b). Tell me more about **the aspects of** change you have made to the crop varieties you planted last season

Have you/Are you...	Code	*Response* ***(00=No, 01=YES)*** *RES*	*If **yes**, to which crops?* *Crop code CRP1*	*Crop code CRP2*	*Crop code CRP3*	*Crop code CRP4*	*Crop code CRP5*	*Crop code CRP6*	*Crop code CRP7*
Introduced new variety of crops	NWVR								
Planting higher yielding variety	PHYV								
Planting better quality variety	PBYV								
Planting pre-treated/improved seed	PPIS								
Planting early maturing variety	SHCY								
Planting longer cycle variety	LGCY								
Planting drought tolerant variety	DRTL								
Planting flood tolerant variety	FDTL								
Planting disease-resistant variety	DSTL								
Planting pest-resistant variety	PSRS								
Testing a new variety	NVTS								
Stopped using a variety	STVR								
Other, specify (SPECCHCP) ✍____________________	OTHE								

c). Tell me more about **what** changes you have made with respect to farm animal since last season and what animal types these changes apply to.

CHANGES IN Farm Animals	***Code***	*Have you made this change to farm animal? **(00=No, 01=Yes**)*	*Farm animal codes (**see farm animal codes**)*						
			FRM1	***FRM2***	***FRM3***	***FRM4***	***FRM5***	***FRM6***	***FRM7***
New farm animal type introduced	NANI								
New farm animal type being tested	NANT								
Stopped keeping one or more types of farm animals	SKFA								
New breed introduced	NBRD								
Reduction in herd size	RDHS								
Increase in herd size	INHS								
Change in herd composition	CHHC								
Stall keeping introduced	STKP								
Fencing introduced	FENC								
Cut and carry introduced	CCIN								
Growing fodder crops	GFDC								
Improved pastures	IMPS								
Fodder storage (e.g. hay, silage)	FDST								
Other kinds of changes not listed above (SPECLIVE) ✍________________________________	OTLS								

d). ***Why*** have you made these changes to your animal keeping and again, to which farm animals were the changes applied to.

Reason for the above animal keeping changes	Code	*Response* *RESP **(00=No, 01=Yes**)*	*Animal code* *(**see farm animal codes**)*							*Not animal specific* ***(01=Yes, 00=No)***
			FRM1	***FRM2***	***FRM3***	***FRM4***	***FRM5***	***FRM6***	***FRM7***	***NASP***
Better price	PRCE									
New opportunity to sell	OPSL									
More productive	MOPR									
More frequent droughts	MDRT									
More frequent floods	MFLD									
Insufficient labour	ISLB									
Able to hire labour	HRLB									
More resistant to diseases	PDRS									
New diseases are occurring	NWPD									
Government/ project told us to	GVTD									
Government/ project showed us how	GVSW									
Policy changes	PLCY									
Other, specify (SPECCHAN) ✍________________________	OTPD									

Section V: Land use management:

a). Tell me more about what changes you have made in the way you manage your land, soil and water and in how you prepared your land -since last season, and which crops these changes affects.

Land Use and management	**code**	*Response (00=No, 01=Yes)*	*If yes, to which crop, Crop code CRP1*	*Crop code CRP2*	*Crop code CRP3*	*Crop code CRP4*	*Crop code CRP5*	*Crop code CRP6*	*Crop code CRP7*
Expanded area	EXAR								
Reduced area	RDAR								
Stopped burning	SPBR								
Introduced intercropping	INCR								
Introduced crop cover	CRCV								
Introduced micro-catchments	MCCT								
Introduced/built ridges or bunds	BUND								
Introduced mulching	MULC								
Introduced terraces	TERR								
Introduced hedges	HEGD								
Introduced contour ploughing	CTPL								
Earlier planting	ELPT								
Later planting	LTPT								
Started using or using fertilisers	MNFT								
Started using manure/compost	MNCP								
Started using pesticides/herbicides	UMPH								
Other, specify (SPECLAND)	WHOT								

b). Agro forestry

	code	*Response*
1. How many trees did you plant on your farm over the last short rainy season?	TREEPLNT	
2. What was the source of the seedlings? (**see codes**)	TREESRSRC	
3. How many trees did you deliberately protect on your farm over the last short rainy season?	TREEPROT	
4. How many trees were damaged/dried over the last short rainy season?	TREEDMGD	
5. In the last short rainy season did you produce any tree seedlings? (***00=No, 01=Yes***)	TREEDPROD	
6. If yes, how many did you plant?	TREEDPNTD	
7. How many did you sell?	TREEDSOLD	
8. How many trees did you plant on your farm last long rainy season?	TREEDPLNT	
9. What was the source of the tree seedlings? (**see codes**)	TREEDSORC	
10. How many trees did you deliberately protected on your farm last long rainy season?	TREEPROT	
11. How many trees were damaged/dried during the last long rainy season?	DAMAGDTREE	
12. Did you produce any tree seedlings last long rainy season? (00=no, 01=yes)	TREEDPROD	
13. If yes, how many did you plant?	TREEDPNTD	
14. How many did you sell?	TREEDSOLD	

NB: ask for exact/estimate the number of trees also if sold try to probe to know the revenue generated

Section VI: - Food Security

I would now like to ask you to describe a **typical food year/season** for your household. For each month, say whether the food you consume is mainly from your own farm or from other sources. In addition, which months if any you tend to find you do not have enough food to eat for your family?

1. **Source of food**	code	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
	FDSC												
Codes for Q1: 01=Mainly from own farm, 02=Mainly from off farm (purchase/aid/other) *Codes for Q2: (01=shortage, 02=No shortage)*													
2. **Shortage / struggle to feed the family**	HUNG												

What are the **three** most preferred type of food crops produced in your household last season? (***See codes***) [__ __]

[__ __]

[__ __]

What are the **three** most preferred food crops you are having a shortage/missing in your households to consider that you are food insecure last season? [__ __]

(***See codes***) [__ __]

[__ __]

What was the key reason for the above most preferred crop failure or shortage? (List three main reasons) [__ __]

(See codes) [__ __]

[__ __]

Section VII: - Climate and Weather Information

***1.** We know that weather is important to farming and would now like to ask you whether you have received any weather information during the last season and what form this takes.*

Type of information	code	*1. Did you receive any information? (01=Yes, 00=No)* ***If No, go to next row.***	*2. From whom or how did you receive the information?**(List up to three) See code sheet***	*3. Who received the information in the household?**(01=Men, 02=Women, 03=Both)***	*4. Did it include advice on how to use the information in your farming? (**01=Yes, 00=No) If No, go to next row.***	*5. Were you able to use the advice?**(01=Yes, 00=No)*** ***If No, go to next row***	*6. What aspects of farming did you change because of this information? **(you can choose up to 3) use the codes***
		RECE	***MSN1, MSN2, MSN3***	***WHO***	***INAD***	***USAD***	***ASP1, ASP2, ASP3***
Forecast of drought, flood or other extreme event	RKEX		1 2 3				1 2 3
Forecast of pest or disease outbreak	RKPD		1 2 3				1 2 3
Forecast of the start of the rains	FCRN		1 2 3				1 2 3
Forecast of the weather for the following 2-3 months	FCMN		1 2 3				1 2 3
Forecast of the weather for today, 24 hours and/or next 2-3 days	FCDY		1 2 3				1 2 3

Section VIII: - Relative change in income sources (livelihoods)

If you are given **10** beans representing your total household income (all possible sources) and were asked to estimate how many of the 10 beans would you allocate to the following livelihood source categories.

Livelihood source		***Previous Season***	***Last Season***						
	code	***SR (2012)***	***LR (2012)***	***SR (2013)***	***LR (2013)***	***SR (2014)***	***LR (2014)***	***SR (2015)***	***LR (2015)***
Livestock	LIVESTOCK								
Crops	CROP								
Off farm	OFFFARM								

<u>Notes/comments:</u>