Carbon Farming Opportunities for Crop Cooperatives in Uganda

Practices, impacts and credit schemes

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A research project submitted to

Van Hall Larenstein University of Applied Sciences

in partial fulfilment of the requirements for

the MSc degree of Agriculture Production Chain Management (APCM)

specialisation Horticulture Value Chains

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This research has been carried out as part of the carbon farming and carbon credits research project of Agriterra 2020

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Acknowledgment

This piece of work in my academic and professional career has been a result of continuous learning and unlearning. It has been a life changing phase in my life that I greatly express my gratitude to the Almighty

My ambition to contribute towards sustainable agriculture in my country was made possible by the opportunity to conduct this in partnership with Agriterra this research commissioner

Academically, I wish to thank Marco Verschuur who facilitated and introduced me to Agriterra and facilitated the research process with them. My mentor, Albertien Kijne, you have been a loving and caring personality throughout this phase of learning in a cross-cultural environment.

I also would like to greatly thank my supervisor, Assoc. Prof. Jerke de Vries and Prof Robert Baars for the guidance and support towards the completion of this project.

Professionally, I extend many thanks to Agriterra supervisors, Niek Thijssen, & Bertken de Leede, for the guidance and support towards accomplishing this work.

Special thanks to Agriterra Business Advisor; Keneth Otima and the team who made my data collection in Uganda possible during the COVID pandemic.

Lastly, I appreciate the support of my Agriterra research project team members
Rugwegwe Olivier Ngirumuvugizi and Marlies van den Nieuwenhof

I hope you enjoy this piece of work

Dedication

To the woman of my life, Lazia Nassanga. my mom.

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List of acronyms

ACP	Agriculture Carbon Project
AFOLU	Agriculture, Forestry and Other Land Use
C	Carbon
CCAFS	Climate Change and Food Security
CCCSs	Compliance Carbon Credit Schemes
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFI	Carbon Farming Initiative
CFP	Carbon Farming Practices
CH_4	Methane
CO_2	Carbon dioxide
CO_{2e}	Carbon dioxide equivalent
CoFPs	Conservation Farming Practices
COP	Conference of Parties
CRAFT	Climate Resilient Agribusiness for Tomorrow
CSO	Civil Society Organization
CT	Conservational Tillage
ETS	European Trading System
FAO	Food Agricultural Organization
FMNR	Farmer Management Natural Regeneration
GHG	Greenhouse Gas
GM	Green Manure
Gt	Gigaton
ICA	International Cooperative Alliance
IFPs	Integrated Farming Practices
INM	Integrated Nutrient Management
JI	Joint Implementation
KACP	Kenya Agricultural Carbon Project
KIT	Royal Tropical Institute
MTIC	Ministry of Trade Industry and Cooperatives
MWE	Ministry of Water and Environment
N_2O	Nitrous Oxide
NAMAs	Nationally Appropriate Mitigation Action plans
NDC	National Determined Contributions
NGO	Non-Governmental Organization
NT	No Tillage
OFPs	Organic Farming Practices
REDD	Reducing Emission from Deforestation and forest Degradation
RT	Reduced Tillage
SACC	Sustaining Agriculture through Climate Change
SALM	Sustainable Agricultural Land Management
SCS	Soil Carbon Sequestration
SLM	Sustainable Land Management
SNV	*Stitching Nederlandse Vrijwilligers* (Netherlands Development Organization)
SOC	Soil Organic Carbon
TIST	International Small Group and Tree Planting Program
UNFCC	United Nations Framework Convention on Climate Change
USA	United States of America
VCCSs	Voluntary Carbon Credit Schemes
VCS	Verified Carbon Standard

WUR	Wageningen University and Research
ZLTO	*Zuidelijke Land- en Tuinbouworganisatie* (Southern Agri- and Horticulture Organisation)

Abstract

Cooperatives are fundamental organizations in small holder agriculture in developing countries. With the rising and immeasurable climate change effects in such economies, cooperatives urgently need to compete as more ecologically as compared to their current economic and social targets. With the deteriorating living conditions for agricultural dependent households owing to the declining productivity, quality and quantity of agricultural land resources carbon farming interventions provide a promising outlook for small holder farmers and their cooperatives to adopt and scale up carbon farming practices within their farming systems. However, they have not been adopted widely nor implemented properly which poses a dilemma for promotion and scale up. This study seeks to investigate various carbon farming practices, economic and ecological effects and trade-offs while exploring opportunities for financial compensation from carbon farming applicable credit schemes, methodologies, entry requirements and risks for cooperatives.

Using a mixed method approach, this study examined documented carbon farming practices, effects and trade-offs from different climate and geographical areas and benchmarked them with the current practices implemented in the Ugandan context amongst cooperatives across 19 districts of the country. The study discovered that at least each of the organic, conservation and integrated farming practices examined were practiced by small holder farmers. Compost, crop rotations and intercropping were most reported and applied CFPS respectively. The study also discovered combinations amongst conservation farming practices had the highest results compared to organic and integrated farming practices. The study reveals farmer bias towards more tangible economic benefits such as yield, income and reduced input. The most reported ecological benefits were soil quality, water holding capacity and pest, disease and weed control. Intangible ecological effects such as carbon sequestration and biodiversity were not a part of the farmers farming life. Consequently, Voluntary carbon credit schemes such as Verra and the Gold standard were identified as the most suitable standards and methodologies which can be used and blended for cooperatives implementing carbon farming. This study opens up opportunities for in-country national compliance schemes to support carbon farming. The study finally reveals that with more economic investment comes more ecological benefits although this requires small holder behavioural change in the transition.

This study provides clarity in form of knowledge and a blueprint for Agriterra and the community of practice for promoting and scaling up carbon farming practices and carbon credits integration with cooperatives in Uganda. Grounded studies in prospected areas and cooperatives are required for precision about zonal agroecological, carbon stocks and social-environment impact assessments prior to implementation.

Key words: *carbon farming, carbon credits, developing countries, cooperatives, NAMAs, NDCs, carbon markets, ecosystem services*

CHAPTER ONE:

1.0 INTRODUCTION

Agriterra is an Internationally renowned Dutch Agri-agency specialist on business development of cooperatives and farmers' organisations in developing and emerging economies (Van Rij, 2020). Agriterra's approach is a three-track by making cooperatives bankable and creates real farmer-led companies, supporting organisations to improve extension services to their members and enhancing farmer-government dialogues (De Leede, 2020). Agriterra emphasises the importance of sustainable service provision by cooperatives and farmer organisations and supports them in providing meaningful and affordable advisory services in order to improve the production and productivity while embedding the promotion of climate-smart approaches (Van Rij, 2015). In so doing, cooperative resilience towards climate change is enhanced through practising adaptation and mitigation measures both at farmers' and cooperative level (Kock, 2020).

1.1 Cooperatives and Climate Change

The International Cooperative Alliance (ICA, 2020) defines a cooperative as "people-centred enterprises owned, controlled and run by and for their members to realise their common economic, social, and cultural needs and aspirations". Cooperatives are also associations of farmers who voluntarily collaborate to pool their production for sale (Agbo *et al.,* 2020). In most developing countries, they have a common business model and play as socio-economic engines that are focused on poor populations (Sumelius *et al.,* 2014). In this way, agricultural cooperatives play an important role in high standard agricultural production and commercialization (Giagnocavo *et al.,* 2017) with an enormous number of farmer members. Around 80% of Uganda's population livelihood is directly reliant on the agricultural sector yet it is the most vulnerable to climate change impacts (MWE, 2015). Given the circumstances, cooperatives must remain competitive and sustainable (Sumelius et al., 2014), amidst the rising and adverse effects of climate change. These effects are gradually reducing the natural resources' capacity and ecosystem services in terms of biodiversity, soil quality and water use and conservation to sustain the food demand of the world's increasing population (FAO, 2019).

The Royal Society (2020) attributes these effects to a series of human activities such as rapid industrialisation in developed countries, accelerated global energy consumption, fuel burning, agriculture, and ozone layer depletion (Sodangi *et al.,* 2011). Frequent and severe occurrences of drought, floods, landslides and hailstorms in developing countries like Uganda and have consequently affected cooperative activities (MTIC, 2011). Despite the fact that the natural processes that minimize these effects are too slow compared to the rates at which human activities are adding Carbon dioxide equivalent (CO_{2e}) to the atmosphere (The Royal Society 2020), cooperatives are caught up in a situation of aggravated and significant environmental consequences (Liu *et al.,* 2016) in form of Greenhouse Gas (GHG) emissions Carbon dioxide (CO_2), Nitrous Oxide (N_2O) and Methane (CH_4) (Burney *et al.,* 2010) released by the Agriculture, Forestry and Other Land Use (AFOLU) sector in which most of them operate. These emissions are mostly a result of farming operations such as; decomposing crop residues, the production and use of inorganic fertilizers, land tillage, spraying pesticides, planting and harvesting crops (Liu *et al.,* 2016) and contribute to around 24% of the worldwide GHG emissions (Foley et al., 2020) making sector the second-largest emitter. Reversing this requires efforts that can reduce such emissions through mitigation and adaptation options that can abate in the restoration of the devastated ecosystems through seizing atmospheric CO_2 into agricultural land soils, a process known as carbon sequestration (Kragt *et al.,* 2012).

1.2 Soil Carbon Sequestration

Climate change models predict that annual reductions in CO_2 emissions of about 3.5–4 Gt could lead to managed increases in temperature by 1.5 – 2° C till 2050 (Minasny *et al.,* 2017). Carbon sequestration in agricultural soils has been identified as a potential strategy to offset GHG emissions amongst various mitigation options in the AFOLU sector that are already being implemented globally (Smith *et al.,* 2014) through a multitude of practices (Smith, 2012). This is because agricultural land soils also known as land sinks can absorb roughly 29% of the CO_2 emissions (without other GHGs) pumped into the atmosphere annually (Foley *et al.,* 2020). However, it is not clear whether this absorption is based on consistency of other CO_2 emission and reduction factors. Carbon sequestration can be achieved by changing agricultural practices and land-use patterns of farmers (Kragt *et al.,* 2012) and degraded soils rehabilitation which are estimated to sequester almost 15% of annual global GHG emissions (Smith *et al.,* 2014). Carbon Sequestration can be achieved through practices such as land use change to ecosystems with higher-equilibrium soil carbon levels; vegetation management via high-input carbon practices, like improved rotations, cover crops, and perennial cropping systems; nutrient management to increase plant carbon returns to the soil, e.g., through optimized fertilizer application rate, type, timing, and precision application; reduced tillage intensity and residue retention; and improved water management, including irrigation in arid conditions (Smith, 2016). Adopters of such practices can enjoy mutual benefits in terms of mitigating the global warming through carbon sequestration as well as improving the soil quality and health as well as economic benefits in terms of improved yield (Sanaullah *et al.,* 2019). These practices are called Carbon Farming Practices (CFPs) which are not limited to; afforestation, adjusting crop rotation, reducing tillage among others (Tang *et al.,* 2019). Consequently, farmers in developing countries like Uganda organized in cooperatives stand a better chance to be positioned at the forefront of climate change mitigation through the adoption of such CFPs during the initial input and production functions of their respective value chains which are climate critical.

1.3 Carbon Farming Initiatives

To position farmers at this forefront requires support and collective effort from both the internal and external institutional environments in which cooperatives operate. Unfortunately, a few countries in the world such as Canada, Australia, USA among others have a specific carbon farming policy in place. Such policies or initiatives are aimed at reducing emissions from agriculture through carbon sequestration for lands under pasture, crops and / or in mixed farming systems (Verschuuren, 2018). In return for the adopted CFPs, a compensation is provided known as carbon credits to farmers registered under these initiatives. In East Africa, there are various carbon projects and initiatives piloted and currently running to support farmers combat climate change effects through CFPs. These include; Kenya Agricultural Carbon Project (KACP), Livelihoods-Mount Elgon project, CARE Sustaining Agriculture through Climate Change (SACC), Humbo Assisted Regeneration Project, International Small Group and Tree Planting Program (TIST), Trees for Global Benefits Program, Emiti Nibwo Bulora among others.

Tennigkeit *et al.,* (2013) argues that the KACP was the first Agricultural Carbon Project (ACP) in Africa that proved that the implementation of CFPs effectively contribute to reduction of GHG, increase small-holder farmers' agricultural productivity, income and strengthen farmers' communities capacity to mitigate and adapt to climate change both individually and through farmer groups. Through such initiatives, farmers have been compensated for the CFPs they adopt on their agricultural lands. However, most of these initiatives and projects are forestry based whose carbon farming interventions are mainly advocating for planting trees under Reducing Emissions from Deforestation and forest Degradation (REDD+) and other renewable energy projects such as cookstoves. More so, most of these have been working with individual farmers thereby contributing to a growing need in the development of Agricultural Carbon Projects which promote CFPs (Shames *et al.,* 2012) amongst small holder farmers organized in cooperatives.

Countries in East Africa such as Uganda whose economy largely relies on agriculture continue to struggle to deliver their 2015 Paris Agreement Nationally Determined Contributions (NDCs) amidst different challenges. With the deteriorating living conditions for agricultural dependent households in such countries owing to the declining productivity, quality and quantity of agricultural land resources (Karanja *et al.,* 2019), the results from the KACP, like improved agricultural productivity, soil fertility, increased income and strengthened farmers' communities' capacity to mitigate and adapt to climate change provide present a promising outlook for small holder farmers and their cooperatives to adopt and scale up CFPs within their businesses. Nevertheless, even where such measures implemented, there are failures because such practices have not been adopted widely and in cases where they have been adopted, they have not been implemented properly (Motavalli et al., 2013). Uganda's NDC implementation urges for research into climate smart and sustainable agricultural practices, like dissemination of good practices and scaling up Climate Smart Agriculture (MWE, 2015) which provides a precedent for this study.

Therefore, as a way of designing CFP scaling approaches in such regions by Agriterra, a clear understanding is needed regarding what CFPs reduce Carbon (C) emissions, their economic and ecological effects, trade-offs and how cooperatives can benefit from the carbon credit schemes. This calls for the need to review current practices and see how credit schemes can support the cooperatives in decarbonising their value chains and business models for them to compete sustainably.

1.4 Problem statement

This poses a dilemma as to why there is no CFP related carbon farming project registered to scale which was piloted and approved in the KACP. This has triggered a need for knowledge as regards what CFPs by small holder farmers in cooperatives in East Africa can be compensated for under CCSs and what the economic effects are in terms of yield, inputs, profitability and what the ecological effects are in terms of ecosystem services while contrasting their economic and ecological trade-offs. More to this is the knowledge gap of the applicability of the various carbon credit schemes, standards and methodologies, entry requirements for cooperatives and risks involved.

1.5 Research objective

In this study therefore, we provide an insight in what these CFPs are, their economic and ecological effects, trade-offs while highlighting CFP agricultural related and specific CCSs, standards methodologies, entry requirements and risks involved. In this way Agriterra can determine their strategy towards the practicalities in supporting CFP's for small holder farmers cooperatives in East Africa. The results of the study shall guide on the formulation of Agriterra's subsequent climate smart programs and abate in policy formulation for carbon farming initiatives for scale up in similar regions of study.

1.6 Research questions

Main Question 1;

Which carbon farming practices can be identified, their economic and ecological effects and trade-offs to cooperatives in Uganda?

1a) What are the existing carbon farming practices in Uganda cooperatives?
1b) What are the economic effects on yield, input and profitability and ecological effects on ecosystem services of the above practices?
1c) What are the economic and ecological trade-offs of these practices?

Main Question 2;

Which Carbon Credit Schemes, standards and methodologies, are there and how can they be integrated, concerning entry requirements and risks into existing cooperative business models in Uganda?

2a) What are the existing Carbon Credit Schemes?
2b) What standards and methodologies are used in the Carbon Credit Schemes?
2c) What are the cooperatives entry requirements for participation in Carbon Credit Schemes?
2d) What are the risks associated with Carbon Credit Schemes?

CHAPTER TWO:

2.0 LITERATURE REVIEW

2.1 Carbon Farming Concept

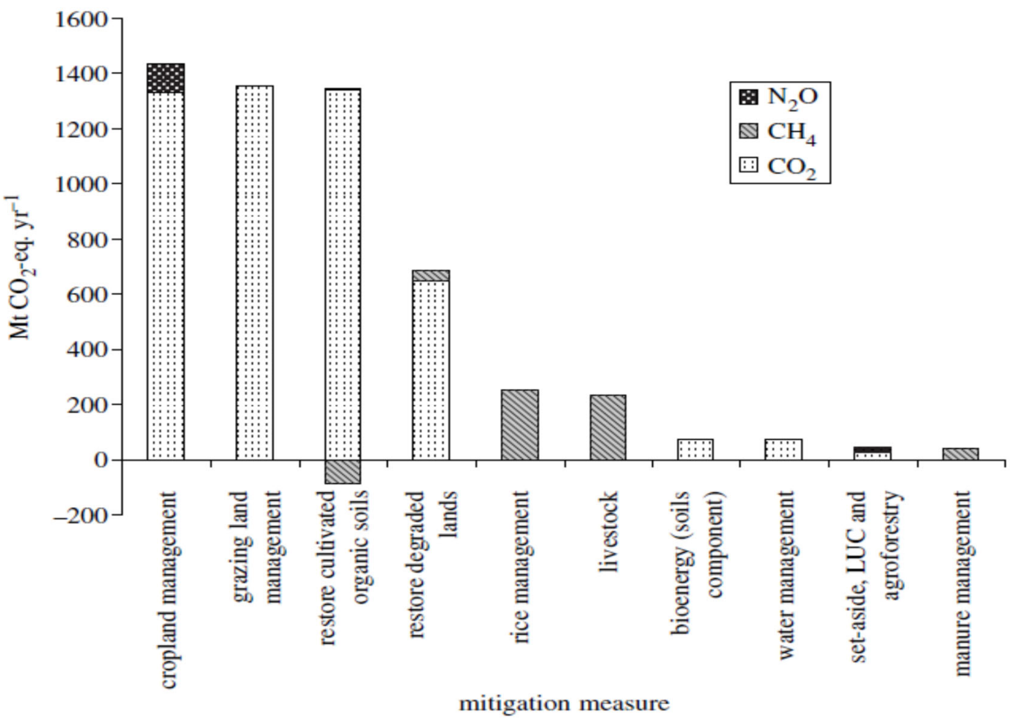
Carbon farming is simply the practice of using known carbon sequestration techniques on various types of farmlands specifically to sequester CO_2 from the atmosphere into soil, and then measuring and reporting results to receive financial compensation (Koplowicz, 2019) from carbon credit schemes. Agriculture is an undisputable contributor to the GHG emissions (Lu *et al.,* 2018) and largely depends on farmers' cropping systems. Hence, farmers play a key role in supplying of low carbon products to the value chains (Liu *et al.,* 2016). It is imperative to explore sustainable food production approaches with minimum environmental costs. CFPs are an implementation of practices that are known to improve the rate at which CO_2 is removed from the atmosphere and converted to plant material and soil organic matter (Nath *et al.,* 2015). They are also a suite of crop and agricultural practices that sequester carbon in the soil and in perennial vegetation like trees or the land use (Toensmeier, 2016). They are farm practices that can sequester carbon in natural sinks such as vegetation and soil (Tang *et al.,* 2019). The commonality in all these definitions relates to the central role that CFPs play in carbon sequestration. In this study we adopt Nath *et al.,* 2015's definition due to its emphasis on plant material and soil organic carbon. In the next section, an exploration of different literature CFPs categorization is introduced, operationalised and expounded as illustrated in figure 1.

Figure 1: Conceptual Framework

2.2 Carbon Farming Dimensions

Smith *et al.,* (2008) categorized CFPs into; agronomy (improved agronomic practices), nutrient management, water management, agroforestry, land cover (use) change, management of organic soils and restoration of degraded lands. A study by Shames *et al.,* (2012) categorised them into; agroforestry, Farmer Management Natural Regeneration (FMNR) and SALM ; Altieri & Nicholls (2013) categorised them into diversification practices and soil management practices; Smith et al. (2014) categorised CFPs into; forestry practices, land based agriculture, livestock and integrated systems, while Shames et.al., (2012) categorized them into; soil nutrient management practices, improved agronomic practices, improved livestock management practices, sustainable energy technologies, restoration of degraded lands soil and water conservation measures, FAO (2016), categorized them into; Conservation Agriculture, integrated soil fertility management, irrigation, agroforestry, crop diversification, improved livestock and feeding practices and others; while Rosa-Schleich et al., (2019) categorised them into single and diversified practices. In as much as different scholars front different dimensions for CFPs, it has been established that most aspects of various CFP dimensions under crop land management remain closely related and have high GHG mitigation potential *(figure 2)*. This categorization is based on the notion that they encompass most of what different literature sources attest in relation the carbon sequestration.

Figure 2: Global GHG mitigation potential ranking of crop land management practices



Source: Smith et al., 2008

Specific indicators of crop land based CFPs dimensions and their aspects covered in this study justified by figure 2 are presented in table 1 and guide the literature, results and discussion chapters of this study,

Table 1: Carbon farming, dimensions, aspects and indicators adopted in the study

Concept	***Dimensions***	***Aspects***	***Indicators***
CROP LAND MANAGEMENT CARBON FARMING PRACTICES	ORGANIC FARMING PRACTICES	COMPOST APPLICATION MANURE APPLICATION BIOCHAR APPLICATION	Number of cooperatives involved in CFP Number of OFPs applied Number of CoFPs applied Number of IFPs applied Number of main crops grown Value chain types Number of value chains functions Number of farming systems Number of CFP supporting policies Access to CFP extension Number of regions under CFP Level of CFP awareness
	CONSERVATION FARMING PRACTICES	NO / REDUCED TILLAGE RESIDUE MANAGEMENT COVER CROPS CROP ROTATION	
	INTERGRATED FARMING PRACTICES	INTERCROPPING AGROFORESTRY AGROPASTORAL AGROSILVOPASTORAL	
	CROSS CUTTING PRACTICES	IRRIGATION INTEGRATED PEST MANAGEMENT INTEGRATED NUTRIENT MANAGEMENT	
ECONOMIC EFFECTS		YIELD INPUTS INCOME PROFITABILITY	
ECOLOGICAL EFFECTS		BIODIVERSITY CONSERVATION PEST, WEED & DISEASE CONTROL POLLINATION SERVICES SOIL QUALITY CARBON SEQUESTRATION WATER HOLDING	
TRADE OFFS			

2.2.1 Organic Farming Practices (OFPs)

OFPs are "a production system which sustains the health of soils, ecosystems and people (IFOAM 2014)". OFPs are often Business as Usual (BAU) in developing country contexts where often low-income farmers having neither access to agricultural input commodities like mineral fertilizers nor pesticides (Müller-lindenlauf, 2009). OFPs possess a global average sequestration potential estimation of 0.9-2.4 Gt CO_2 per year (Niggli *et al.,* 2009) and are proposed to enhance top-soil organic carbon (SOC) stocks in croplands (García *et al.,* 2018). Since OFPs comprise of a variety of practices (Leifeld & Fuhrer, 2010), the next section focuses on; compost application, manure application, and biochar application as potential amendments for soil fertility and soil carbon increment (Gattinger *et al.,* 2012).

Compost Application

Compost is an outcome of recycling processes which is a very appropriate input material for organic farming (figure 3) if the composting process is well-managed (Van der Wurff *et al.,* 2016). Compost can be applied as a fertilizer to increase plant productivity, soil health conditioner, mulch, and peat replacement (Vergara, 2012). According to Van der Wurff *et al.,* (2016), traditional composts are commonly made of a combination of manure and plant residues. The manure provides nitrogen (N), phosphorus (P) and potassium (K) nutrients while its microorganisms enable a fast decomposition process, once exposed to enough levels of moisture and oxygen. Al-Sari *et al.,* (2018) recommended the use of compost in agriculture but stressed the need for improving the quality of the compost products for proper environmental safeguarding. A study by Nguyen *et al.,* (2013) suggested compost augmentation with other amendments such as urea, thermo phosphate, animal manure and effective micro-organisms to enhance composting time and quality. The use of earthworms to convert organic materials into humus-like material as known as vermicomposting (Lim *et al.,* 2014) is supported to avoid the unnecessary disposal of vegetative food wastes (Rogayan *et al.,* 2010).

Figure 3: An illustration of compost ready for farm application

Source: Van der Wurff et al., 2016

Munroe (2007) and Ngo *et al.,* (2012) argue that soil carbon levels are drastically raised by consistent application of compost hence contributing to the overall climate change mitigation benefit. However, Biala (2011) cautioned about the awareness of raw materials to be composted for composting systems, but most importantly for estimating CO_2 evolution. This is so because the composting process itself is likely to emit CH_4 (Silver et al., 2018), Nitrogen loss (Biala, 2011) hence the need for safeguards to lower emissions and increase the net benefit from the practice. However, study by Jjagwe *et al.,* (2019) denoted that GHG emissions in vermicomposting method were low compared to composting and stockpiling.

Manure Application

Organic manure is one of the most common materials applied in agricultural management (figure 4) to improve soil quality and crop productivity (Liu *et al.,* 2013) and one of the most effective ways of improving fertility in tropical soils (Kihanda *et al.,* 2006). Manure composition highly varies according to animal type, diet, housing type, the amount and type of litter, water used, length and storage conditions, and treatment measures influence the amount of gaseous losses and loss of organic matter and nutrients (Van der Wurff *et al.,* 2016). The consistent addition of animal manure increases soil C stocks in agricultural soils such as poultry, cows, pigs, goats, sheep, sludge and biosolids application (Sanaullah *et al.,* 2019).

Figure 4: An illustration of manure ready for farm application

Source: Van der Wurff et al., 2016

More so, 26 years long-term study by Li *et al.,* (2018) reported an 86% increase in SOC stock through applying the organic manure compared to mineral fertilizers. Zhang *et al.,* (2016) recommends manure application in combination with other CFPs as way of increasing soil carbon sequestration. Sanaullah *et al.,* (2019) conclude that animal manure is indeed more efficient than crop residues for enhancing SOC stocks. However, in as much as manure is the second largest source of greenhouse gas (GHG) emissions, combining manure and urea, can reduce agricultural emissions without compromising productivity (Olaleye *et al.,* 2020).

Biochar Application

Biochar is a charcoal produced under high temperatures (300° to 500°C) through the process of pyrolysis using crop residues, animal manure, or any type of organic waste material (Bracmort, 2010). Pyrolysis is the thermal decomposition of organic materials such as crop residues, chaff, shell, straw, shank, in a low oxygen atmosphere (Roobroeck *et al.,* 2019). For the local context, Mekuria & Noble (2013) assert that biochar can be produced using locally made technologies, which can be easily used and accessed by local farmers.

Figure 5: An illustration of manure ready for farm application

Source: Mekuria and Noble 2013

Biochar amendment in agricultural soils has been proven by several studies to be an effective CFP for mitigating GHG emissions (Zhang *et al.,* 2020). The total amount of C that could potentially be added to soils in Uganda through biochar from the five crops investigated by Roobroeck *et al.,* (2019) while Lehmann (2007) refutes possibilities of SOC loss after its incorporation hence a lower risk CFP compared to compost and manure in terms of leakage.

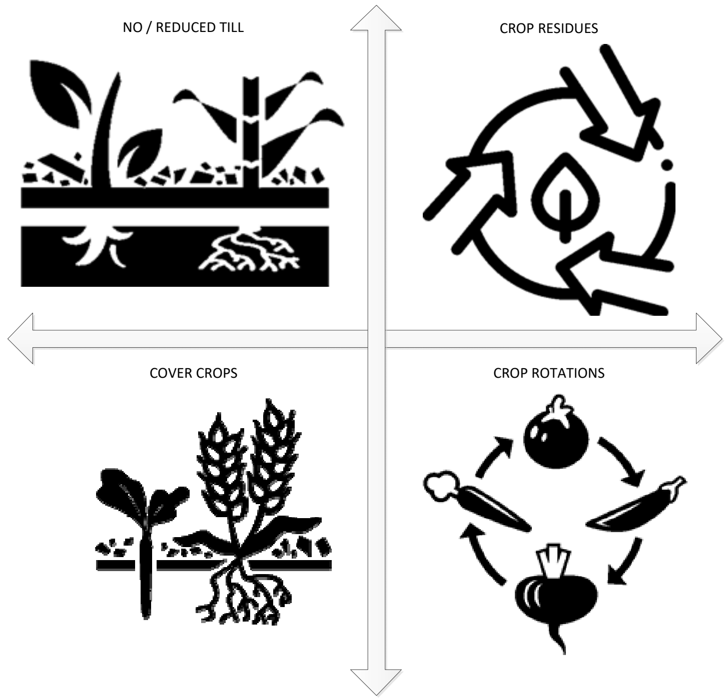
Scholarly evidence presented in the section suggests that compost, manure and biochar is a suitable amendment for plant productivity and soil organic carbon but with significant GHG emissions. Safeguards have been explored to ensure quality and minimise such environmental harms. Consequently, dilemmas about rightful quantities, consistent supplies (for compost and manure), competing household uses of residues for biochar and technologies need precision before implementation.

2.2.2 Conservation Farming Practices (CoFPs)

CoFPs are a system of agronomic practices that include reduced tillage (RT) or no-till (NT), permanent organic soil cover by retaining crop residues, and crop rotations, including cover crops (figure 6) (Palm *et al.,* 2014; Lee *et al.,* 2019; Foley *et al.,* 2020). While CoFPs were not initially considered as a soil carbon sequestration practices, they are now widely considered as a potential technology to mitigate GHG emissions and reduction of fossil fuel consumption (Delgado *et al.,* 2011). CoFPs are hailed for increased profits and food security, improved and sustained productivity and ecological preservation

(Friedrich *et al.,* 2012). As scholarly definitions fronted above suggest, CoFPs interact and are acclaimed for their capacity to lessen trade-offs between ecosystem services and capitalize on synergies between them (Palm *et al.,* 2014).

Figure 6: An illustration of the CoFPs covered in this study



Source: Author's compilation 2020

Reduced Tillage (RT) or No-till (NT) Practices

Reduced tillage (RT) also known as Conservation Tillage (CT) is a practice of minimising agricultural soil mechanical disturbance. The process allows crop residues to remain on the ground. RT practices may progress from reducing the number of tillage practices to stopping tillage completely also called zero tillage or no till (ZT or NT). The negative effects that intensive tillage-based farming systems generally have had on the quality of ecosystem services (Friedrich *et al.,* 2012) cannot be ignored hence the relevance of NT or RT proposition and basis for study and application on a wider scope (Eagle *et al.,* 2011). Sanaullah *et al.*, (2019) asserts that NT and/or RT CoFPs are proposed to sequester C in as much as its adoption does not enhance SOC when but re-distributes SOC along the soil profile. Different CFPs can be aligned with NT to promote aerobic organic matter decomposition as a mitigation strategy for reducing GHG emissions (Ortiz-Monasterio *et al.,* 2010). Such combinations can be with crop residues (Zhang *et al.,* 2018); manure application (Zhang *et al.,* 2016); mixed cropping systems (Luo *et al.,* 2010); optimal levels of Nitrogen (Ghosh *et al.,* 2020) although SOC increases are often confined to near-surface layers (Palm *et al.,* 2014).

Crop residues

Crop residues are detached vegetative parts of crop plants that are purposely left to degenerate in agricultural fields after crop harvesting (Tanveer *et al.,* 2019). Since most agricultural crop residues are 40% to 50% C on a dry weight basis, their presence and management on the soil surface is extremely important for maintaining soil quality, SOC and soil fauna activity (Delgado *et al.,* 2011). In addition, Walia & Dick, (2018) found that addition of crop residues along with mineral fertilizers increased the SOC storage from 4.38% to 4.44% making the retention of crop residues essential for increasing or maintaining soil C (Palm *et al.,* 2014). More recent studies acknowledge that the accumulation of SOC stocks in top soils when crop residues are maintained with RT (Zhang *et al.,* 2018). This CoFP is implemented through a process called mulching and was the most effective method amongst CoFPs to increase SOC in a study by Lee *et al.,* (2019).

Cover crops

Cover crops also known as green manure (GM) are the plants grown within agricultural fields to improve soil fertility, prevent soil erosion, enrich, protect soil, enhance nutrients, quality and water availability of soil. (Sharma *et al.,* 2018). Cover crop increase SOC return directly through their shoots and indirectly through higher biomass and residue production (Sharma *et al.,* 2017; White *et al.,* 2020). These findings also support Eagle *et al.,* (2011)'s assertion regarding cover crops' as a promising GHG mitigation CFP.

Crop Rotations

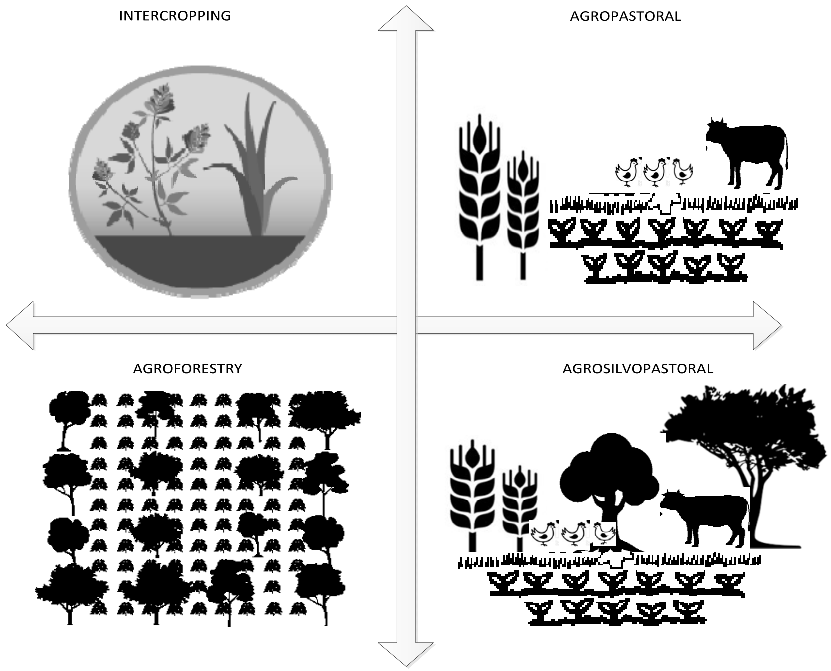
Crop rotations are crop sequences grown in frequently repeated successions on the same area of land (Tanveer *et al.,* 2019; Sanaullah *et al.,* 2019). Growing of crops frequently on the same piece of land exhausts the soil and is common practice amongst small holder farmers in developing countries perhaps due to the size of their land. The potential of crop rotations in C sequestration has been fronted on the premise upon selection of appropriate crop rotations according to the soil and environmental conditions (Tanveer *et al.,* 2019) as a result of biomass production and C inputs from the different crops in the system (Palm *et al.,* 2014). As a way of multiplying the benefits of crop rotation in terms of SOC and nutrient stocks and cycling, Sanaullah *et al.,* (2019) suggests a combination with other CFPs such as intercropping and leguminous cover crops as did McDaniel *et al.,* (2014) whose study found out that adding one or more crops in a monoculture led to an increase in SOC content.

Scholarly evidence presented in the section suggests that No / Reduced till helps to safeguard against leakage of captured CO_2 by crop residues, cover crops, crop rotations and other OFPs due to reduced soil disturbances. To this effect, attention to specific crops to be used is of great significance due to the nitrogen and nutrient fixation and depletion roles amongst inappropriate crops.

2.2.3 Integrated Farming Practices (IFPs)

Oliveira *et al.,* (2018) defines IFPs also known in form of *diversified*, *mixed* and *polyculture farming* system as a production measures that combine crops with crops, livestock and trees on the same farm area (figure 7). However, Gil *et al.,* (2015); Liu *et al.,* (2016) and Oliveira *et al.,* 2018 argue that these can be conducted in different ways; integration of crop–livestock (*agropastoral*), crop–forestry (*agroforestry*), livestock–forestry (*silvopastoral*) and crop–livestock– forestry (*agrosilvopastoral*) and can be useful in largely reducing the system's carbon footprint compared with conventional monoculture systems. This land sharing concept is fundamental in ecosystems services enhancement, such as carbon storage, pest control, pollination and climatic change adaptation (Goulart *et al.,* 2016). Evidence underpinning IFP adoption suggests that non-intensive agricultural, biodiversity-friendly, and ecosystem-preserving agricultural systems (such as agroforestry) should be pursued to balance conservation with environmentally and socially sound agriculture (Perfecto & Van der meer, 2010). They have therefore become a widely studied concept, as they seek to achieve enhanced production with reduced impacts on the environment (Oliveira *et al.,* 2018). It is also worth noting that the most salient feature of IFPs is *agro-pastoral* (Antle et al., 2018) while the concept has also proven effective for *agroforestry* cases such as shade cocoa (Clough *et.al.,* 2011) and coffee shades (Komar, 2006). While most IFPs can lead to soil C increase, their effects on GHG emissions can be variable resulting in either climate mitigation potential (Sanderson *et al.,* 2013).

Figure 7: An illustration of the IFPs covered in this study



Source: Author's compilation 2020

Intercropping

Intercropping can be defined as "a multiple cropping system that two or more crops planted in a field during a growing season" (Mousavi *et al.,* 2011). The use of intensified intercropping with reduced tillage coupled with residues on the soil surface increased grain production and reduced carbon emissions (Hu *et al.,* 2014). More to this, results from a study by Cong *et al.,* (2014) indicate that soil C sequestration potential of intercropping is similar in magnitude to OFPs that conserve organic matter in soil.

Agropastoral practices

Agropastoral also known as integrated crop-livestock systems are a common and default system in smallholder settings. The system is largely interdependent where crop residues are harvested for livestock fodder and livestock manure for soil amendment (Peterson, *et al.,* 2020). Results of the first agropastoral study by Peterson *et al.,* (2020)'s meta-analysis showed the potential of agropastoral systems such as ecological intensification CFPs has on cultivated lands while fostering resilience to the effects of climate change with minimum environmental harms.

Agroforestry practices

Foley *et al.,* (2020) defines agroforestry as a suite of tree intercropping systems in which trees are grown together with annual crops in an area at the same time. In this way, systems may use trees to support annual crop production through nitrogen fixation, or as protective systems against erosion, flooding, or wind damage and having trees as crops themselves like strip intercropping of annual crops with timber or fruit trees. A variety of agroforestry practices exist today such as; windbreaks, alley cropping, silvopasture, riparian buffers, and forest farming (Eagle et al., 2011). Agroforestry is an important CFP for producing annual crops while sequestering carbon in soils and aboveground biomass (Foley *et al.,* 2020) in which a large portion of organic C returns to the soil in the form of crop residues and tree litter (Lorenz & Lal 2014). A study by Cardinael *et al.,* (2015) however, contends that combining agroforestry with CoFPs like no-till or cover crops can be efficient way to increase SOC stocks although additional SOC in agroforestry is mainly located in topsoil layers and in labile organic fractions hence rendering it vulnerable. On the other hand, the conversion from usual agriculture to agroforestry led to significant increments in SOC stocks by inclusion of perennials with agroforestry systems (De Stefano & Jacobson, 2017).

Agrosilvopastoral

Agrosilvopastoral is defined as an IFP that combines agroforestry and livestock grazing on the same piece of land (Soler *et al.,* 2018). Gil *et al.,* (2015) affirm that the potential of SOC increase via organic matter enhancement is achievable through agrosilvopastoral combinations in the same area. This notion is also supported by De Stefano & Jacobson, (2017) who reported significant increases in SOC in the top layers of agrosilvopastoral systems.

The evidence presented in this section exhibits the multiple carbon sequestration potential both above and below soil. This is due to the IFPs implementation synergies from amalgamation by crops, livestock and trees systems. The diversity of such integration at farm level requires diversity precision of contextual studies if sustainable production targets are to be met.

2.2.4 Crosscutting practices

Irrigation

Moisture in most agroecosystems conditions does not remain same throughout a crop's cycle hence varying effects on soil C mineralization (Sanaullah et al., 2019). Effective water harvesting, recycling, at farm levels have proven enhanced SOC sequestration and improve farm productivity (CRIDA, 2012). This notion is supported by Franco-Luesma *et al.*, (2020)'s study that suggests that no-tillage, maintaining the crop residues and irrigation resulted in lower soil CO_2 emissions and biomass maintenance. More recent studies have continued to affirm that irrigation practices can greatly influence GHG emissions because of their control on soil microbial activity and substrate supply (Sapkota *et al.,* 2020). As a result, incorporation of water resources management into CFPs as a mitigation and adaptation measure in paramount because of the strong soil-water connection (Lal *et al.,* 2017).

Integrated Nutrient Management (INM)

In most developing countries the soil fertility is enhanced majorly through over application of chemical fertilisers which is ecologically destructive (Wu & Ma, 2015). INM is the application of reduced amounts of inorganic fertilisers in supplementation with organic amendments. The practice has proven potential for yield increment and reduced N losses and GHG emissions (Wu & Ma, 2015). The application of organic fertilisers and reduced doses of inorganic fertilisers has a positive effect on soil properties as well as increased Soil organic matter and nutrient availability due to the enhanced microbial activities (Patra *et al.*, 2020)

Integrated Pest Management (IPM)

Today, pest impact reduction is more inevitable than ever for global food security, pesticides application reduction and GHG emissions reduction per unit of food produce (Heeb et al., 2019) IPM is "a science-based, decision-making process that identifies and reduces risks from pests and pest management related strategies through coordination of the use of pest biology, environmental information, and available technology to prevent unacceptable levels of pest damage by the most economical means, while minimizing risk to people, property, resources, and the environment." (USDA, 2018). Most contemporary farming and pest management practices largely lead to environmental degradation hence a threat to food systems and natural resources sustainability (Baker et al., 2015). Due to reduced chemical application on agricultural soils, IPM and INM are vital in carbon sequestration (Lal, 2006)

Weed Management

Proper weed management does not only to prevent crop yield loss, but also to minimize weed seed reserves in the soil (Naresh, 2018). While small holder farmers employ hand weeding strategies and herbicides with varying effect on the environment, different studies suggest numerous weed management strategies such as cover crops (Mondal et al., 2015), crop rotations, (Anderson, 2010), mulching no till (Beamer, 2018).

The evidence presented in this section shows the inevitability of irrigation, nutrients, pest, disease and weed management during CFP implementation. Without proper attention to how these CCPs are implemented across various farming systems under CFPs, efforts to reduce and / or sequester CO_2 may be rendered useless such as using OFPs in some farming system components while neglecting others. Investigation of how farmers manage these under different farming systems could be a focal and starting point prior to CFP promotion

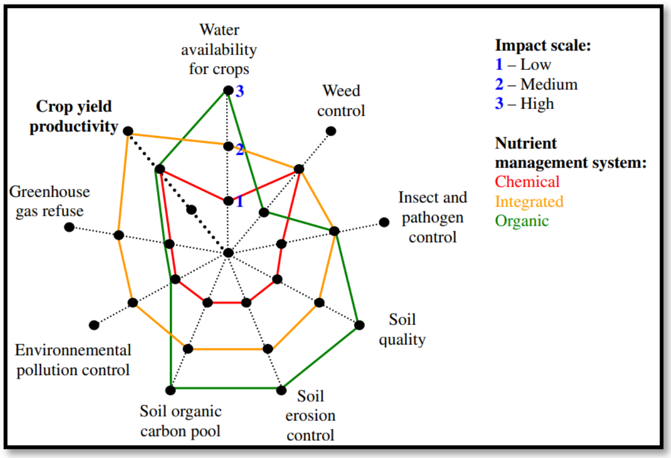
2.3 Economic and Ecological effects of CFPs

CFPs presented in this study are ideally a generic overview of practices investigated across diverse geographic, climatic conditions, soil properties and cropping systems. The previous outlay reflects their role in climate change mitigation and potential in sequestering CO_2 while reducing other GHG emissions. The economic effects in this study are scored against economic variables yield, inputs, income and profitability (Rosa-Schleich *et al.,* 2019) while their ecological effects of the CFPs investigated are scored against ecosystem service variables such as; biodiversity conservation, control of pests, weeds and diseases, pollination services, soil quality, enhanced carbon sequestration and water-holding capacity in surface soils (Kremen & Miles 2012).

Organic Farming Practices

OFPs adoption presents positive outcomes for both economic and ecosystem services (figure 8). Economically, these practices have an increased market for organic products and premium prices in developed countries hence an opportunity for increase farm profitability (Müller-lindenlauf, 2009). OFPs generally increase soil fertility and biological diversity (Knapp & van der Heijden, 2018). Compost addition to the soil was reported to increase yields, fruit weight and soil organic carbon build up (Jindo *et al.,* 2016). Compost further contributes to soil ecosystem resilience (Van der Wurff *et al.,* 2016), improved chemical, physical, biological soil properties, reduced input usage (Biala, 2011).

Figure 8: Spider chart showing OFP effects



Source: Stavi et al, 2016

Other co-benefits of compost include; higher soil nutrient content and nutrient retention, more water retention capacity, reduced erosion, better plant (e.g. crop and forage) productivity, lower soil compaction (Conant, 2011) and capacity to control plant diseases due to its suppressive effect on plant pathogens (Rogger *et al.,* 2011). Composting of organic waste and compost usage result in lower GHG emissions reduced nutrient leaching, reduced water use (Koplowicz, 2019). Vermicomposting, a process of using earthworms for organic matter decomposition is a better supplement to improve and stimulate plant growth (Lim *et al.,* 2014) Manure application is reported as one of the most effective ways of improving soil fertility (Kihanda *et al.,* 2006) and crop yield increase (Blanchet *et al.,* 2016) because it provides nutrients for crops while improving water quality (Delgado *et al.,* 2011). Biochar together with compost have been proven to improve soil fertility and plant-available water-holding capacity Liu *et al.,* (2016). This organic amendment can also increase crop yields (Mekuria & Noble, 2013; Katterer *et al.,* 2019 and Roobroeck *et al.,* 2019), reduced global warming potential, GHG emission intensity, increased crop yield (Zhang *et al.,* 2020), better soil quality, and crop growth (Yang et al., 2020). Other biochar proponents also argue that biofuels are produced during biomass pyrolysis which can act as a source of renewable energy (Karhu *et al.,* 2011), suppressing CH_4 and N_2O emissions (Jeffery et al., 2013) and inducing systemic pest resistance in some plant species (Meller Harel *et al.* (2012)

Table 2 Literature summary of general OFP economic and ecological effects

Economic		***Ecological***	
Improved farm productivity	*Shames et al., 2012*	*Enhancement of soil ecological health functions*	*Sanaullah et al., 2019*
Diversified incomes	*Shames et al., 2012*	*Biodiversity protection*	*Tang et al., 2016b*
Reduced chemical fertiliser and pesticide use	*Freibauer et al., 2004*	*Increased water holding capacity*	*Shames et al., 2012*
Premium price markets for organic produce	*Müller-lindenlauf, 2009*	*Degraded landscapes rehabilitation*	*Masiga et al., 2012*
Increase yields & fruit weight	*Jindo et al., 2016* *Katterer et al., 2019*	*Soil erosion control*	*Masiga et al., 2012*

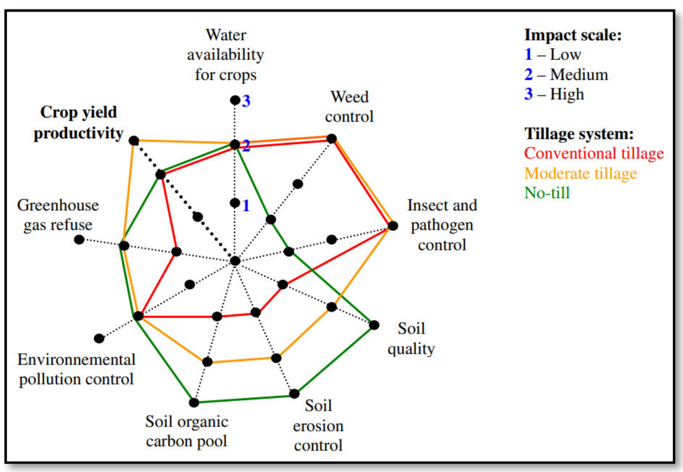
	Crop drought and flood tolerance	*Smith et al., 2014*
	Soil organic carbon build up	*Jindo et al., 2016*
	Capacity to control plant diseases	*Rogger et al., 2011*
	Lower GHG emissions & reduced global warming potential	*Zhang et al., 2020*
	Reduced nutrient leaching	*Koplowicz, 2019*
	Source of renewable energy	*Jeffery et al., 2013*
	Balanced ecosystem services provisioning	*Chabert & Sarthou 2020*

Conservation Farming Practices

Rosa-Schleich *et al.,* (2019) asserts that CoFPs are a lucrative system with valuable effects on soil health and quality, as well as other ecosystem services (figure 9). They are a way of enhancing farmers' income with low costs of production while conserving natural resources (Kiran *et al.,* 2020), soil water conservation in semi-arid environments, facilitate the increase of SOM, reduce CO_2 emissions to atmosphere (García-Tejero *et al.,* 2020), increased yield, biomass and enhanced ecosystem service supply (Lee *et al.,* 2019).

No-till is hailed as a panacea for multiple ecosystem benefits (figure 4) soil erosion (Seitz *et al.,* 2018) and low productivity (Gattinger *et al.,* 2011), improved soil fertility (Tang *et al.,* 2019), commended for improvements in both soil carbon and crop produce (Sun *et al.,* 2020) as well as reduced GHG emissions (Powlson *et al.,* 2014).

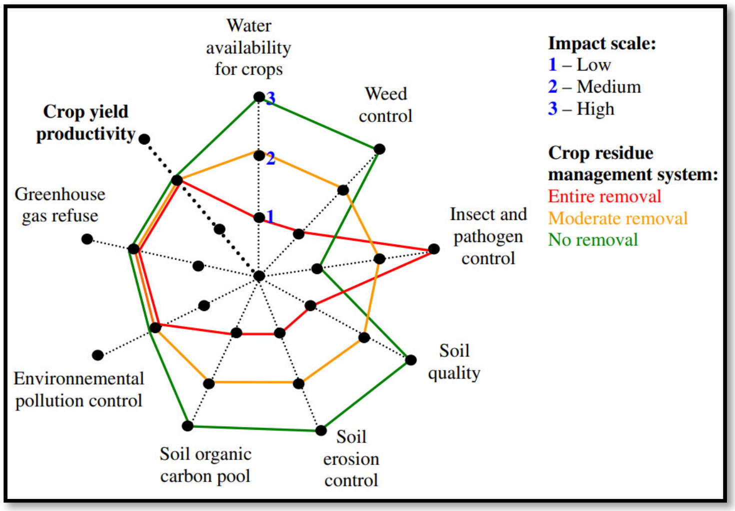
Figure 9: Spider chart showing the effects of No Till



Source: Stavi et al, 2016

Findings from Lu, (2020)'s meta-analysis affirm that crop yields increased when crop residue return was used hence a pivotal role it plays in refurbishing soil productivity because of its varied effects on soil physical, chemical and biological properties. It helps building up organic carbon, conserves soil moisture, moderates soil temperature, reduces soil erosion, nitrogen immobilization and weed infestation (Srinivasarao *et al.,* 2014). Other studies such as Zhang. *et al.* (2016) and Smith *et al.,* (2008) indicate that increasing crop residue is the most effective approach to enhance SOC stocks and helps to maintain soil structure which is beneficial to various soil organisms (Blanchet *et al.,* 2016). Figure 5 illustrates the various effects of crop residue management.

Figure 10: Spider chart showing the effects of crop residues



Source: Stavi et al, 2016

Cover crops are known to increase crop quality and soil productivity (Sharma *et al.,* 2017), increases carbon sequestration rate Sánchez *et al.,* (2016), conserve the environment, reduce the rainfall intensity that falls on the ground, fight against pests, help to reduce pesticides use, accommodating beneficial insects, attract pollinators for improving the rate of pollination in crop lands (Sharma *et al.,* 2018), decrease runoff and soil loss (Lee *et al.,* 2019) reduce N_2O emissions, enable reduced energy use for fertilizer production and significantly a promising GHG mitigation CoFP (Eagle *et al.,* 2011).

The potential of crop rotations as a CoFP is envisaged in improving soil fertility, reduce the emissions of CO_2 increase farmer's income (Tanveer *et al.,* 2019). More to this, crop rotations help increase biomass production and C inputs from the different crops, alters pest cycles helps in the diversification of rooting patterns and rooting depth (Palm *et al.,* 2014). It is economically viable in-terms of lower input costs, increased long-term yield, and risk reduction for farmers (Rosa-Schleich *et al.,* 2019).

Table 3: Literature summary of general CoFP economic and ecological effects

Economic		***Ecological***	
Enhancing farmers' income	*Kiran et al., 2020*	*Conserving natural resources*	*Kiran et al., 2020*
Low costs of production	*Kiran et al., 2020*	*SOM increase*	*García-Tejero et al., 2020*
Increased yield	*Lee et al., 2019*	*Reduce atmospheric CO_2 emissions*	*García-Tejero et al., 2020*
Low productivity	*Gattinger et al., 2011*	*Soil erosion control*	*Seitz et al., 2018*
Crop yield increase	*Sun et al., 2020*	*Improved soil fertility*	*Tang et al., 2019*
Reduced pesticides use	*Sharma et al., 2018*	*Weed control*	*Srinivasarao et al., 2014*
Lower input costs	*Rosa-Schleich et al., 2019*	*Reduce the rainfall intensity*	*Sharma et al., 2018*
		Pest control	*Sharma et al., 2018*
		Improved pollination services	*Sharma et al., 2018*

Integrated Farming Practices

In IFPs, inputs from one enterprise like crops come from products of another enterprise like livestock and vice versa. They rely on well-functioning ecosystem services such as water cycling, disease and pest suppression, hence contributing to input-reduction and improved productivity (Sanderson *et al.,* 2013). Without soil health ecosystem services in IFPs, monocultures are left to solely depend on off-farm inputs like synthetic fertilizers and pesticides (Kremen & Miles, 2012) and as such, management decisions leading to increased soil C in IFP contribute to increased agroecosystem resilience to combat climate change (Sanderson *et al.,* 2013).

Intercropping helps to improve soil fertility due to more efficient nutrient use and reducing fertilizers application rate Sánchez *et al.,* (2016) which is more important in the tropics and sub-tropics where soils are naturally low in available nutrients (Kremen & Miles, 2012). Intercropping also increases yield when combined with reduced tillage residue mulching on the soil surface while effectively lowering carbon emissions (Hu *et al.,* 2014). It also increases yield, overpowers weeds, and improves soil quality (Sánchez *et al.,* (2016).

Agroforestry is associated with various benefits such as biodiversity conservation (Eagle *et al.,* 2011), diversified income sources (Delgado *et al.,* 2011) and increased production (Reed *et al.,* 2017). They also use trees as support for annual crop production through intercropping, as shielding systems against erosion, flooding, or wind damage while trees in other systems are crops with fruits and timber (Foley *et al.,* 2020). They contribute to income and promoting afforestation while improving soil health, water-holding capacity in surface soils, increase pollination services, and enhance pest, disease and weed control (Kremen & Miles, 2012).

In as much as agropastoral systems showed no impact on crop yields in large scale industrialized systems (Peterson *et al.,* 2020), this IFP have proven economic gains inform of diluted fixed costs and shareable inputs, which result in economies of scale (Mendonça *et al.,* 2020). On the other hand, the combination of crop, livestock and/or trees increases soil fertility and organic matter content (Gil *et al.,* 2015).

Table 4: Literature summary of general IFP economic and ecological effects

Economic		***Ecological***	
Improved productivity	*Sanderson et al., 2013*	*Disease and pest suppression*	*Sanderson et al., 2013*
Input-reduction	*Sanderson et al., 2013*	*Improve soil fertility*	*Sánchez et al., 2016*
Yield improvement	*Sánchez et al., 2016*	*Lowering carbon emissions*	*Hu et al., 2014*
Diversified income sources	*Delgado et al., 2011*	*Weed suppression*	*Sánchez et al., 2016*
Increased production	*Reed et al., 2017*	*biodiversity conservation*	*Eagle et al., 2011*
		Soil erosion and flooding control	*Foley et al., 2020*
		Improved water holding capacity	*Kremen & Miles, 2012*
		Enhance pest, disease control	*Kremen & Miles, 2012*
		Organic matter content	*Gil et al., 2015*

2.4 Economic and ecological trade-offs of CFPs

The main goal of CFP adoption lies in reducing GHG emissions which involves change of practices that collide with crop production goals in both positive and negative forms (Lee *et al.,* 2016) which results into trade-offs. Trade-offs occur when a CFP owing to more ecosystem services is adopted by farmers at the expense of economic benefits and vice versa. It is argued that CFPs are generally expensive (Tang *et al.,* 2016b) Win-win situations may be possible by combining an awareness of what CFPs may produce a trade-off with an understanding of why and what trade-offs result to create the synergies sought for better outcomes (Howe *et al.,* 2014). A critical dilemma is often faced by farmers who in order to make a profit must make their systems as efficient as possible and thus switching to CFPs often implies completely transforming business operations (Nijman, 2019). On the other side, CFPs may not currently be as productive (Kremen & Miles, 2012) farmers are likely to only voluntarily adopt such practices if economically profitable (Kragt *et al.,* 2012). Generally, CFP adoption at farm scale could result in land-use change such farm expansion into forest land which remains, perhaps, the most potent global threat to biodiversity conservation (Morán-Ordóñez *et al.,* 2017). More to this, are the high costs, skills, knowledge, yields compromises, farming system incompatibilities, farm business uncertainty alongside land tenure rights (Kragt *et al.,* 2017).

Organic Farming Practices

In this study most CFPs are often inadequate to control pests and diseases or provide enough pollination and it has been argued that OFPs often lead to reduced crop yields (Ramankutty et al., 2019) whereas composting and vermicomposting processes during waste stabilization emit a considerable amount of GHGs such as CO_2 and CH_4, (Swati & Hait, 2018). The application of manure on agricultural fields without proper management results into pollution swapping (De Vries *et al*, 2015). In the case of biochar application in the tropical agricultural systems, the removal of crop residues for or by livestock, either through grazing or cut and carry, is a common practice (Mekuria & Noble, 2013) hence competing uses for crop residues, like soil surface cover and animal fodder and construction which affect its realistic availability (Roobroeck *et al.,* 2019). This practice also involves removal of crop residues from agricultural lands which is likely to increase risk of accelerated erosion and depletion of ecological resources to accumulate large quantities of biochar (Mekuria & Noble, 2013). The application of biochar requires injection into deeper soil layers which results into a no till trade-off (Jeffery et al., 2013)

Table 5: Literature summary of general OFP economic and ecological trade-offs

Economic		***Ecological***	
Lead to reduced crop yields	*Ramankutty et al., 2019*	*Inadequate to control pests and diseases*	*Wittwer et al., 2017*
Competing uses for crop residues	*Mekuria & Noble, 2013*	*Provide insufficient pollination*	*Wittwer et al., 2017*
		GHG pollution swapping	*De Vries et al, 2015*
		Increase risk of accelerated erosion	*Mekuria & Noble, 2013*
		Leads to soil disturbance	*Jeffery et al., 2013*

Conservation Farming Practices

The productivity benefits cover crops, mulches, compost manure are often short-lived due to high decomposition rates especially in the tropics. More-so, SOC can be leaked in cases of conversion from no-tillage back to conventional tillage (Mekuria & Noble, 2013). In terms of pest, weed and disease control, no till was proved to have more influence on pests such as the common vole (Roos *et al.,* 2019) as well as enhanced herbicide application on crop lands to fight against weed (Rosa-Schleich *et al.,* 2019: Gattinger et al, 2011) In addition, most of these CoFPs are currently not part of the traditional practices in Sub Saharan Africa which hinders their rates of adoption (Palm *et al.,* 2014). Crop residues are a major source of livestock feed across most smallholder mixed systems (Valbuena et al., 2012)

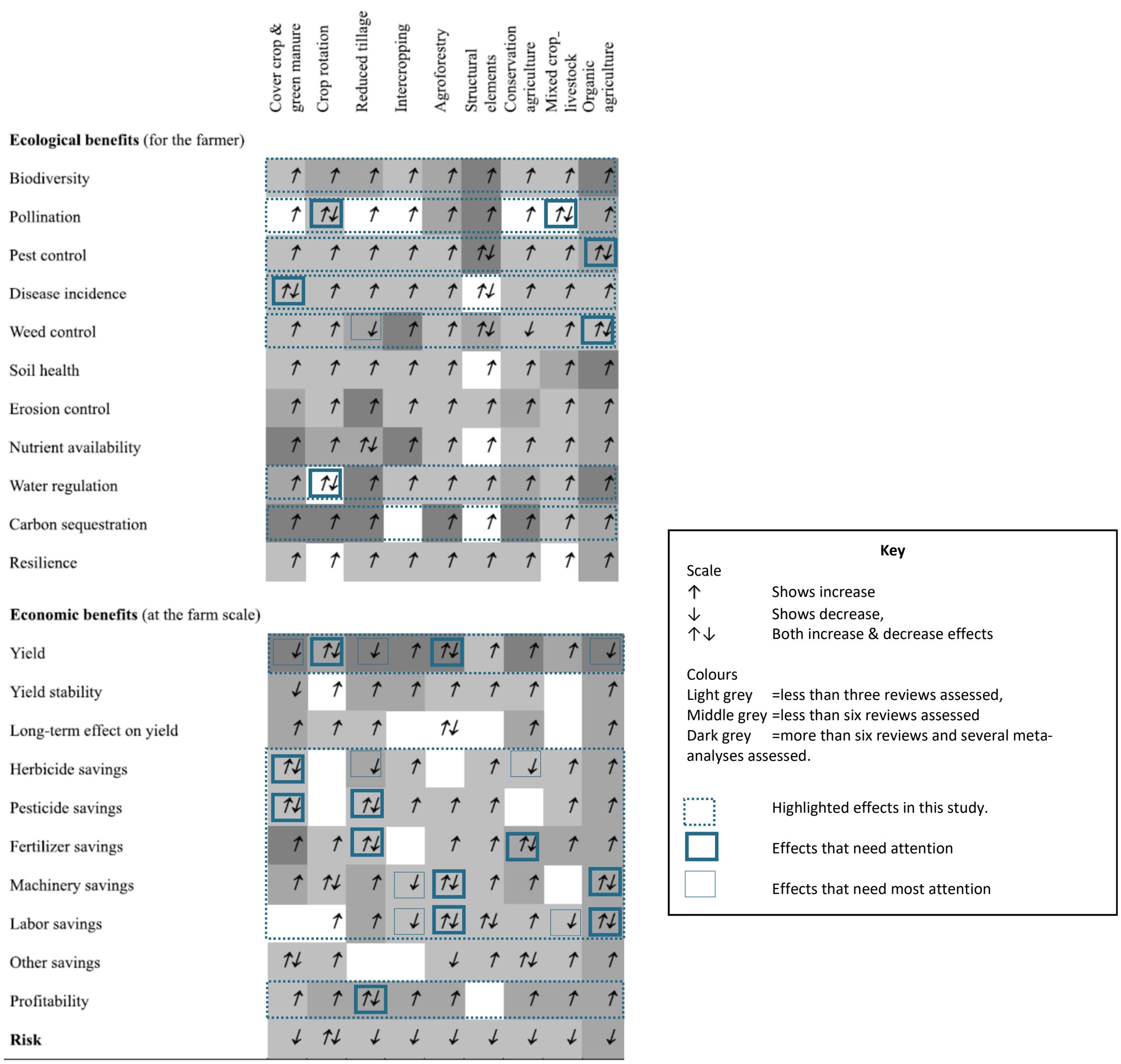
Table 6: Literature summary of general CoFP economic and ecological trade-offs

Economic		***Ecological***	
Crop residue competing uses	*Valbuena et al., 2012*	*High decomposition rates hence short-lived benefits*	*Mekuria & Noble, 2013*
		Minimum pest, weed and disease control	*Roos et al., 2019*
		Enhanced herbicide application on crop lands	*Rosa-Schleich et al., 2019*

Integrated Farming Practices

Some of the complexities surrounding the implementation of IFPs are embedded in the requisite know-how and technical knowledge, management complexity, machinery, implementation maintenance labour and input costs (Gil *et al.,* 2015 & Rosa-Schleich *et al.,* 2019). These can be sabotaged if there is a decreasing labour supply or increasing labour costs (Archer *et al.,* 2018). More so, the interaction between integrated crop, livestock and trees systems in the tropics still require more necessary evidence precision in order to upscale (Reed *et al.,* 2017). Switching to IFPs in favour of high SOC sequestration is likely to reduce to farm profits (Kragt, *et al.,* 2012) and often comes at the expense of lost productivity (Smith *et al.,* 2008). This study has explored studies conducted about CFP economic and ecological effects although studies involving conclusive trade-offs are few. A meta-analysis by Rosa-Schleich et al., 2019 attempted to explore CFP trade off with outcomes illustrated in figure 11.

Figure 11: CFP effects and trade-offs from various literature sources



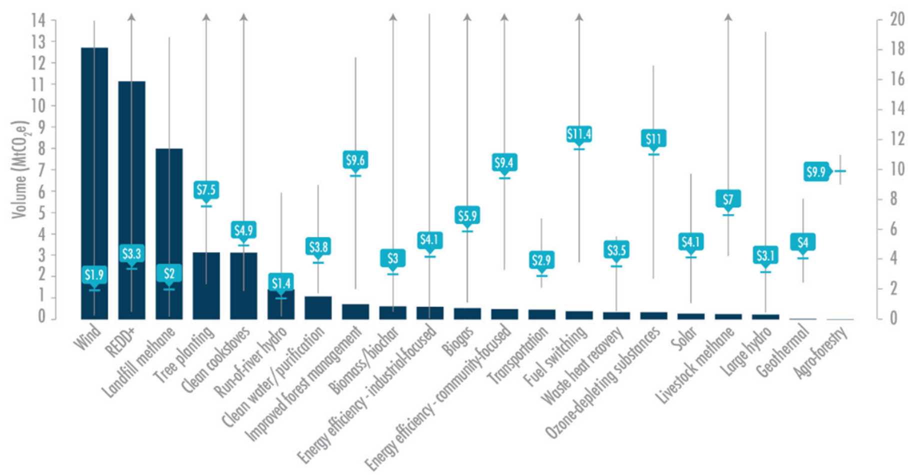
Source: Rosa-Schleich et al., 2019

This section of the CFP literature has provided an outlook for CFP promotion by the community of practice. Evidence presented as augmented by the above meta-analysis jointly provide a basis for CFP implementation on grounds of presented positive effects maximised upon CFP combination. As far as trade-offs portrayed herein are concerned, attention of great significance in specific contexts of implementation is needed. Perhaps with more contextual and comprehensive evidence of financial instruments intervention for sustainable farming, this lays a foundation for linking cooperatives implementing CFP to Carbon Credit Schemes for financial compensation as presented in the next section.

2.5 Carbon Credit Schemes (CCSs)

Carbon Credit Schemes trace their origins back to the United Nations Framework Convention on Climate Change (UNFCC) Kyoto Protocol of 1997 which set out quantified binding commitments to limit or reduce GHG emissions for 40 industrialised nations (Arnoldus & Bymolt, 2015). CCSs also known as carbon markets have been presaged as a prospect for financing low carbon development in in developing countries and climate change mitigation (Howard *et al.,* 2016). They have emerged as with potential for emission reductions through trading credits also known as carbon offsets paid to producers/farmers at a price per Certified Emission Reductions (CER) (Arnoldus & Bymolt, 2015). CO_2 is the principal GHG, carbon is traded like any other commodity at a price (*figure. 12*). Carbon pricing refers to schemes that put a monetary value on GHG emissions per tCO_2e. This includes carbon taxes, offsetting mechanisms, and emissions trading among others. These schemes run under international, national and voluntary credit schemes play a role of shifting the burden for climate change effects back to those who are responsible most especially in the developed world. However, critics of CCS argue that these mechanisms are frontline for continued emissions by offsetting if little emission reduction efforts are made by companies.

Figure 12: Sector specific carbon prices



Source; Ecosystem Marketplace, (2018)

2.6 Carbon Credit Schemes Dimensions

2.6.1 International Compliance Schemes

These are schemes governed by the UNFCCC international climate treaties and administered by the United Nations The first historic compliance dimension of carbon credit schemes developed by the UNFCCC was the Kyoto Protocol of 1997 through which selected developed countries were required to cut down their emissions through the International Emissions Trading and Joint Implementation. Nationally Appropriate Mitigation Actions (NAMAs) as another compliance dimension set out for climate change mitigation in this study was first used during the Bali Action Plan of 2007 and endorsed in the UNFCCC COP 13 Copenhagen. Thirdly is the 2015 UNFCCC Paris Agreement that led to the development of country specific Nationally Determined Contributions (NDCs) in which all countries were obliged to set own climate change targets and commitments. Hence it becomes clear that the UNFCCC carbon markets are the main compliance CCS because they were established for their participants to meet binding targets set by governments (Carbon markets watch, 2020). As a result, there are close to 50 compliance markets that are already up and running worldwide, as more grow in upcoming years (World Bank, 2019). In this study, we explore the dimensions in *table 7*

Table 7: Carbon Credit Concepts, Dimensions, Aspects and Indicators of the study

Concepts	***Dimensions***	***Aspects***	***Indicators***
CARBON CREDIT SCHEMES	INTERNATIONAL COMPLIANCE SCHEMES	CLEAN DEVELOPMENT MECHANISM	Number of CFP applicable schemes Number of CDM CFP methodologies Number of voluntary schemes Number of voluntary CFP standards Number of CFP applicable methodologies per standard
	NATIONAL COMPLIANCE SCHEMES	NATIONAL APPROPRIATE MITIGATION ACTIONS NATIONAL DETERMINED CONTRIBUTIONS	
	VOLUNTARY SCHEMES	PRIVATE SCHEMES	
	STANDARDS AND METHODOLOGIES	CDM STANDARD VERRA STANDARD GOLD STANDARD	
	ENTRY REQUIREMENTS		
	RISKS		

Clean Development Mechanism (CDM)

The Clean Development Mechanism (CDM) is a cornerstone of the Kyoto Protocol which was conceived as a global compliance market for offsetting emissions (Ecosystem marketplace, 2019). It was among other emission ambitions designed to support developing countries to achieve sustainable development using foreign investments as a way of accomplishing their set targets (Pešić *et al.,* 2018) and was the largest and most widely accepted project-based standard for offset projects which were mainly energy based (Arnoldus & Bymolt 2015). Within the CDM mechanism, carbon credits generated from forestry were categorised under the banner of afforestation/reforestation (A/R) (Arnoldus & Bymolt 2015). However, CDM 54% drop in credit volumes between 2016 and 2018 (Ecosystem marketplace, 2019).

Until now, there are no carbon farming related carbon offset projects within the UN carbon offset platform and the CDM registry. The program faces an uncertain future that will be decided by two key upcoming negotiations around Article 6 of the Paris Agreement hence, many CDM project developers have turned to the voluntary markets to try and find buyers (Ecosystem marketplace, 2019). The CDM is criticised for having failed to include a mechanism to finance activities that work to address tropical deforestation (Ecosystem marketplace, 2019). In addition to this, of about 7,000 registered active CDM projects in the world, as little as 2.5% is related to agriculture and only 0.6% to forestry (Pešić *et al.,* 2018).

2.6.2 National Compliance Schemes

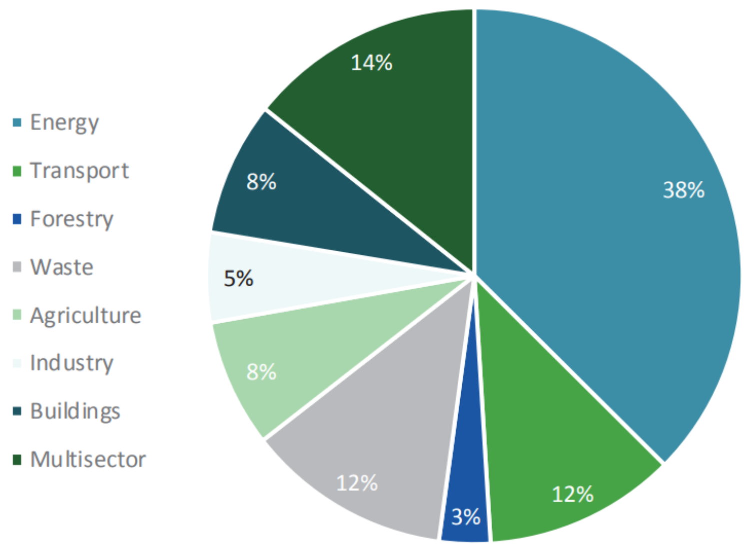
These are schemes initiated and governed by respective countries according their jurisdictional legislature. Some of these may be as outcome of international compliance mechanism or government initiatives. These have been a boom of the cap and trade policies or carbon taxes with the Colombia as the largest national carbon market in the world. In Africa, South Africa is the only country that has adopted the carbon tax.

Nationally Appropriate Mitigation Actions (NAMAs)

NAMAs emerged during the Bali Action Plan was agreed at the United Nations Climate Change Conference in December 2007 in recognition for the need for developing country efforts to design, manage and own emission reductions strategies. NAMAs can be viewed as policies, programmes and projects that developing countries undertake to contribute to the global effort to GHG emission reductions in prioritised sectors.

Currently there are 259 NAMAs and 35 feasibility studies in 69 countries to explore amongst which majority of them fronted the AFOLU sector as their prioritised basis for emission reductions (Afanador *et al.,* 2017). Agricultural based mitigation NAMAs are gaining traction (*figure 4*) Until now, NAMAs still offer a capable apparatus for enhancing climate change reduction policies and measures, upon fund availability in most developing countries. NAMA monitoring and verification is not as stringent as the that for carbon market projects.

Figure 13: Sectoral prioritisation of country NAMA submissions



Source: Afanador *et al.,(* 2017)

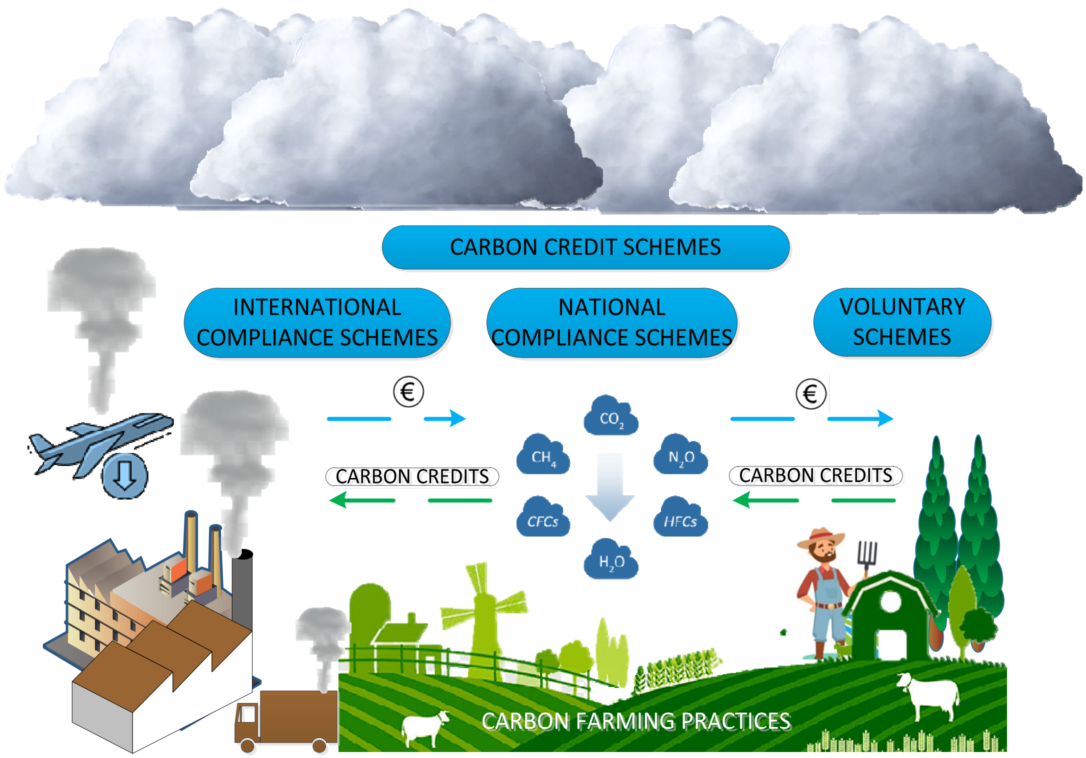
Nationally Determined Contributions (NDCs)

In 2015, 196 countries and parties of the UN came together under the Paris Agreement to transform their development trajectories on a sustainable development course towards limiting warming to 1.5 to 2^0 C above pre-industrial levels (UNFCCC, 2015). Article 4.2 of the Paris Agreement States that; "*Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions*" (UNFCCC, 2015). This article forms the ultimate basis upon which country NDCs were founded and developed.

As a result, all countries possess climate targets, compared to the Kyoto Protocol and this has led to the establishment of the country and voluntary carbon markets. These markets are covered extensively by Article 6 of the agreement (Carbon markets watch, 2020). The Paris Agreement establishes the main framework for cooperative action on climate change beyond 2020 and is set to replace the Kyoto Protocol. Today, NDCs act as a substantial catalyst for mitigation actions across sectors and at all scales, from local projects to national policies and these developments enhance the need for transparent reporting on the impact of diverse mitigation actions (USAID, 2019).

Pešić *et al.,* (2018) argues that the 2015 Paris Agreement is insufficient and ineffective because NDCs are legally non-binding and lack the specificity, obligation necessary to become enforceable. More so, international climate protection policy without a mechanism to force a country to fulfil its declared intentions is doomed a failure (Druzin, 2016).

Figure 14: An illustration of how carbon credit schemes work with carbon farming practices



Source: Author's compilation 2020

2.6.3 Voluntary Carbon Credit Schemes (VCCSs)

VCCSs are legislation-free schemes that allow corporations and people to counterbalance their carbon emissions on a purely charitable basis by buying carbon credits produced from projects that either decrease GHG emissions or capture carbon from the atmosphere (Arnoldus & Bymolt 2015). In these voluntary markets, farmers can choose to sell carbon credits for additional CO_2 sequestered in vegetation or soils as a result of a change in land use or management practices (Kragt *et al.,* 2012). VCCSs encompasses all exchanges of carbon offsets that are not under regulation by either International or national mechanisms. An astonishing feature of the voluntary carbon markets is that buyers are often enthusiastic to pay a higher price for non-carbon benefits such as biodiversity preservation and livelihoods improvement.

As voluntary action on climate gains momentum, corporates in developed countries are demonstrating an appetite to the Paris Agreement by committing to carbon neutrality. As a result, global carbon reduction projects financed by the private sector on a voluntary basis have already reduced over 500 million tons of CO_2e (ICROA, 2020). An opportunity rises in VCCS in a way that many private sectors entities are expressing an interest in either developing their own projects or investing in high-impact projects at an early stage (Ecosystem Marketplace, 2020). These buyers prefer projects that demonstrate benefits beyond emission reductions with verified co-benefits and tangible stories rather than unitized, tradeable co-benefits but these products are still new and their willingness to pay a premium is limited (Ecosystem Marketplace, 2019).These schemes are not backed by any government standard or mandatory goals, but rather based on specific organisations therefore operations rest on the relationship of trust between buyers and the GHG programmes, and the claim that the credits sold on the market truly contribute to reducing emissions (Carbon markets watch, 2020).

Evidence explored in this section portrays that governments have planned emission reductions strategies as well as international compliance obligations. Significant progress has been made by voluntary schemes while in country emission reductions schemes are slow to this effect. Technical and financial incapacities play in fundamental role in developing relevant emission reduction programs such as CFP promotion

2.7 Standards and Methodologies

The compliance and voluntary schemes have designed methodologies within their standards for use in different carbon projects across various sectors. In agricultural carbon projects, SOC sequestration needs to be verifiable by measurements and approved calculation methods whose availability depends on the type of carbon stock and land use system in order to credible in carbon markets (Müller-lindenlauf, 2009). It should also be noted that established standards for voluntary transactions are increasingly being considered for inclusion in compliance markets (Ecosystem marketplace, 2019). We explore the only international various methodologies for standards that are applicable for carbon farming.

2.7.1 Compliance Standards and Methodologies

CDM Standard methodologies

Afforestation and reforestation of lands except wetlands (AR-ACM0003)

This methodology applies to afforestation and reforestation activities. This falls under the mitigation category GHG removal by sinks through increasing of carbon stocks in; above-ground biomass, below-ground biomass, and optionally: deadwood, litter, and soil organic carbon (UNFCCC, 2019).

Methane emission reduction by adjusted water management practice in rice cultivation (AMS-III.AU)

This methodology applies to rice farms that change the water regime during the cultivation period from continuously to intermittent flooded conditions and/or a shortened period of flooded conditions and falls under the mitigation category of GHG emission avoidance through reduced anaerobic decomposition of organic matter in rice cropping soils (UNFCCC, 2019)

Reduction of N_2O emissions from use of Nitrogen Use Efficient (NUE) seeds that require less fertilizer application (AMS-III.BF)

This methodology is applicable for the use of a genetically distinct type of seed for crops that will utilize nitrogen more efficiently and falls under the mitigation category of GHG emission avoidance through avoidance of N_2O emissions from agricultural activity by reducing the amount of fertilizer used by the crop (UNFCCC, 2019).

2.7.2 Voluntary Standards and Methodologies

Verified Carbon Standard methodologies

Methodology for Sustainable Agricultural Land Management (VM0017)

This methodology applies to the application of farming practices that increases the carbon stocks on the land such as manure management, use of cover crops, and returning composted crop residuals to the field and the introduction of trees into the landscape among others (VCS, 2011).

Methodology for Improved Agricultural Land Management (Under Development)

This methodology provides procedures to estimate the GHG emission reductions and removals resulting from the adoption of improved agricultural land management practices focused on increasing SOC storage though regenerative agriculture (VCS, 2020). It envisages the implementation of one or more new agriculture practices such as reduced fertilizer (organic or inorganic) application, improved water management/irrigation, reduced tillage, improved residue management, improve crop planting and harvesting like; improved agroforestry, crop rotations, cover crops and/or improved grazing practices.

Gold Standard methodologies

Soil Organic Carbon framework methodology (402)

The methodology aims to reduce GHG emissions from agriculture by quantifying changes in GHG emissions and soil organic carbon (SOC) stocks through the adoption of improved agricultural practices. It is applicable for a wide range of activities, from small scale, low tech land use to industrialized, large scale land management, using a variety of SOC improvement approaches that enhance SOC through sequestration and avoid emissions (Gold Standard, 2020).

Soil organic carbon activity module: increasing soil carbon through improved tillage practices (402.1)

This module falls under the Soil Organic Carbon framework methodology and aims to reduce GHG emissions from agriculture by changing soil tillage practices within agricultural systems through conservation tillage practices such as reduced/minimum/no tillage, direct drilling and strip cropping (Gold Standard, 2020).

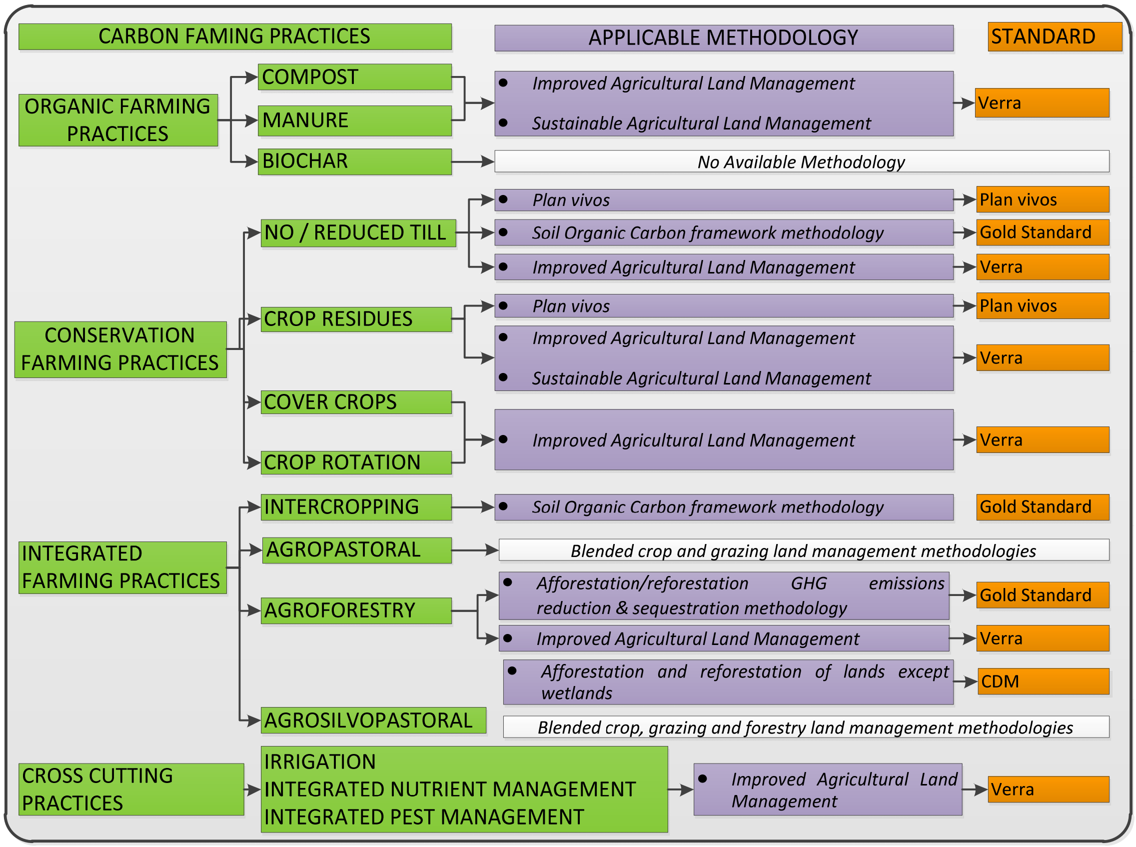
Afforestation/reforestation GHG emissions reduction & sequestration methodology (401.13)

This methodology seeks to enabling A/R activities to quantify and certify emissions sequestration impacts through the planting of trees on land and supports all silvicultural systems such as conservation forests (no use of timber), forests with selective harvesting, rotation forestry as well as agroforestry and silvopasture activities (Gold Standard, 2017).

Plan vivos standard methodologies

This is a voluntary standard designed to guarantee that projects benefit livelihoods, enhance ecosystems and protect biodiversity. It offers an agenda for the impartial transaction of ecosystem services with communities and allows access to a range of funding sources and markets. Carbon farming eligible activities include improving land use and land use management activities to increase the provision of ecosystem services, e.g. reduce greenhouse gas (GHG) emissions and/or increase carbon stocks such as non-burning of in-field residues or no/minimum till agriculture (Plan Vivo Standard, 2013).

Figure 15: Summary of methodologies under the different standards



2.8 Entry requirements for cooperatives

Perez, (2007) asserts that there are preconditions that must be met for an integration of farming management strategies such CFPs into CCSs. Project development is currently the only way through which cooperatives can participate in CCSs. Designing and developing a carbon project takes a long time, necessitates a lot of technical know-how and substantial financial resources for the preliminary set-up (Arnoldus & Bymolt 2015). Project development involves five major phases which include the predevelopment phase, the development and validation phase, the monitoring reporting and verification phase and the carbon credit issuance phase. Requirements for each stage are summarized in table 9.

Table 8: Summary of carbon credit scheme entry requirements for cooperatives

Phase		***Requirement***	***Document***	***Source***
Pre-Project Development (PPD)	*1.*	*Project Idea*	*Project Idea Note*	*Seeberg-Elverfeldt, (2010)*
	2.	*Financial resources planning*		*Seeberg-Elverfeldt, (2010)*
	3.	*Stakeholder mapping*		*Masiga et al., (2012)*
	4.	*Project Developer Contract*		*Seeberg-Elverfeldt, (2010)*
	5.	*Carbon scoping study*		

Development, Validation and Registration (DVR) phase	*6. Carbon feasibility study*	*Project Design Document (PPDD)*	*Seebauer & Tennigkeit, (2020)*
	7. Project documentation design		
	8. Management Information System development		
	9. Third party auditors	*Validation Report*	
	10. Project registration		
Project Management and Implementation (PMI)	*11. Project administration team and facilitation*	*Letter of Approval (LoA)*	*Masiga et al., (2012)*
Monitoring and Reporting and Verification (MRV)	*12. Overseeing of project carbon credit generation personnel and tools*	*Monitoring records*	*(Seebauer & Tennigkeit, 2020)*
	13. Periodic reporting and communication tools		
	14. Third party verifiers	*Verification Report*	
Carbon Credit Issuance (CCI)	*15. Credit issuance and certification*	*Emission Reduction Purchase Agreement (ERPA)*	*Broekhoff et al., (2019)*
	16. Entry into registry		
	17. Brokers / retailers on/off exchange		
	18. Credit purchase and transfer to buyers		
	19. Credit retirement		
	20. Claiming		

2.9 Risks

Participation in CCSs poses various risks that are underpinned by different literature sources such as additionality, permanence, and leakage (Metz *et al.,* 2007). Additionalities must be addressed by ensuring CFP interventions contribute to an added carbon sequestration compared to BAU. Permanence also means that measure should be taken to ensure that carbon sequestered has permanence and could be leaked back to the atmosphere. The risks summarised in table 9 can be political, operational, performance, physical, regulatory, project based, contractual, credit based, and market-based CII, (2009)

Table 9: Summary of carbon credit scheme risks

Phase	***Risk***	***Source***
Pre-Project Development (PPD)	*Unclear property rights of beneficiaries*	*CII, (2009)*
	little or no stakeholder and institutional support	
	inadequate financial resources	
Development, Validation and Registration (DVR)	*Additionality, permanence, leakage risks*	*Broekhoff et al., (2019)*
	Poorly / Incorrect written baseline studies	*CII, (2009)*
	Monitoring methodologies	
	Over/under estimation volumes	
Project Management and Implementation (PMI)	*Political risks in form of confiscation/nationalisation/expropriation,* *Currency inconvertibility,* *War, strikes, riots, host country letter of approval revocation & country withdrawal or non-renewal from the International UNFCCC Agreements*	*CII, (2009)*

	Production risks	
	Environmental & social risks, *Equipment delivery/transit,* *Calamities like fire, windstorm, floods or earthquakes, epidemics,*	*CII, (2009)*
Monitoring and Reporting and Verification (MRV)	*Performance,* *MIS Technology efficacy,* *DOE/VVB absence error or omission*	*CII, (2009)*
Carbon Credit Issuance (CCI)	*Market risks in form of;* *Price fluctuations,* *Carbon credit price risks,* *Forward crediting,* *International Transaction Log risk* *Credit default by project developer* *Lack of financial closure,* *Credit default by DOE/VVB* *Double counting (issuance, use and claiming)*	*Broekhoff et al., (2019)*

Overall, there are not many carbon farming applicable methodologies presented in this section mostly with voluntary schemes. Specific CFP interventions ought to adopt current methodologies, blended methodologies or develop new ones. Whereas entry requirements for mainly rely of technical and financial capabilities of the cooperative, risks can be mitigated and managed both before and during project implementation.

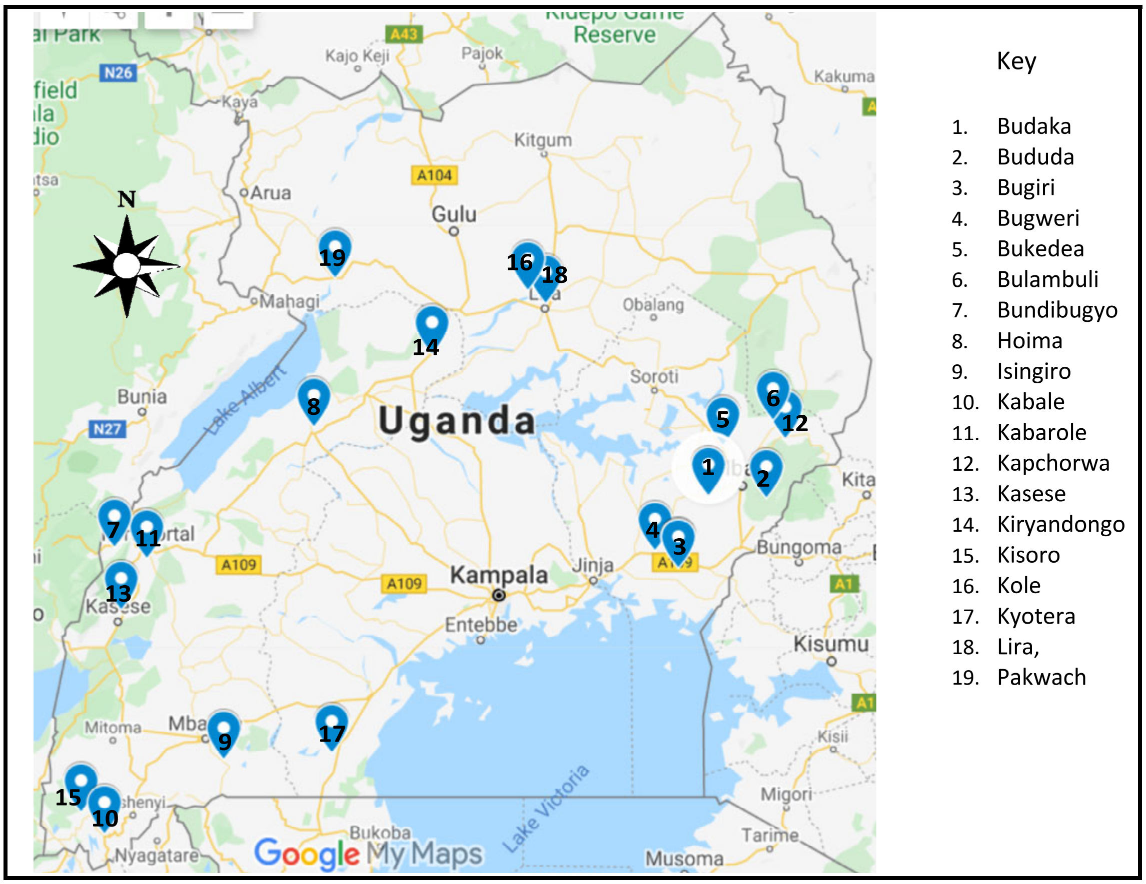
CHAPTER THREE:

3.0 METHODOLOGY

3.1 Study area

The study was conducted across Agriterra cooperatives in Uganda. Uganda is a member country of the East African Community under the Climate Resilient Agribusiness for Tomorrow (CRAFT) project is currently being implemented by SNV (lead) in partnership with Agriterra, CGIAR's Research Program on Climate Change Agriculture and Food Security (CCAFS), Wageningen University and Research (WUR), Rabo Partnerships in Kenya and Tanzania. Cooperatives represented in this study are in 19 out of 134 districts (figure 16) within the 5 regions of the country which have all suffered climate change disasters like floods, mudslides and drought. Uganda's most important sector of the economy is agriculture, employing 72% of the work force with significant natural resources including fertile soils, regular rainfall, substantial reserves of recoverable oil, and small deposits of copper, gold, and other minerals (CIA, 2020). In addition to the climate change effects, the country's general productivity is hindered by several supply-side constraints, including insufficient infrastructure, lack of modern technology in agriculture, and corruption (CIA, 2020).

Figure 16: Map of Uganda showing districts of cooperative respondents



Source: *GoogleMyMaps 2020* ©

3.2 Research design

Given the prevailing effect of the COVID-19 pandemic on international travels and social distancing measures by governments world all over, the study adopted on-line qualitative and quantitative approaches in which both primary and secondary data sources were used to collect data. Farmer interaction and observation for quantitative CFP responses were not possible due to social distancing and curfews by the Uganda government. More so, remote connection to farmers was not possible due to network coverage and poor internet connectivity. As a result, representatives of cooperatives were sought to respond to the online survey. The sample size, data collection and analysis tools are presented in the following sections.

3.3 Sample size

A total of sample of n=43 was selected for the study of which (*n=28*) were on-line survey respondents. *15* were Agriterra client cooperatives and 13 were non Agriterra client cooperatives in Uganda selected by convenience sampling. Online interviews with key informants (*n=15*) were conducted of which 6 were from Uganda while 9 were international selected by convenience sampling

3.4 Data collection tools

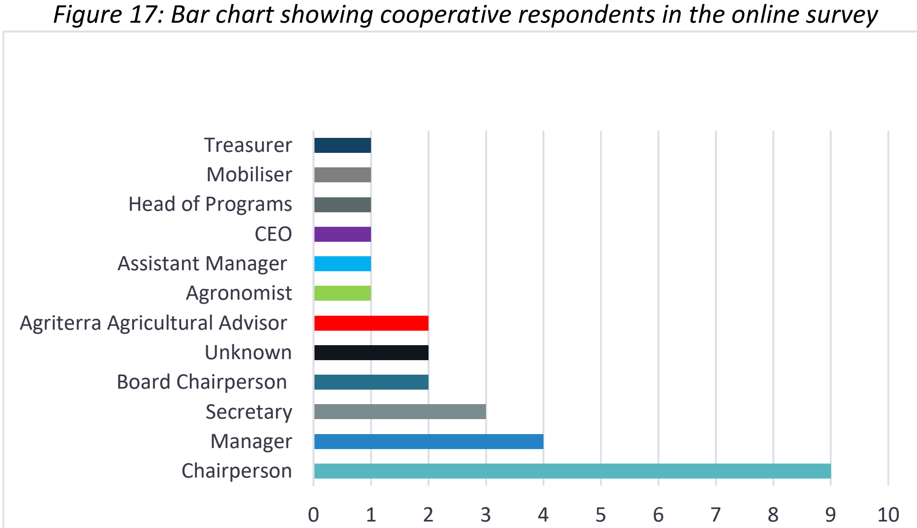
Desk study

Secondary data (literature) was collected through extensive desk study using online sources on the internet. The remote *Greeni* tool and Google Scholar were used to gain access to various scholarly peer reviewed journal articles and grey literature.

Online- survey

An online survey across selected cooperatives in Uganda was carried out. The survey was designed by use of Microsoft office forms and sent to Agriterra business advisors in the country to be filled by representatives of the cooperatives (figure 17). Cooperatives with internet access provided an exploratory and general overview about Carbon Farming Practices, ecological and economic trade effects as well as trade-offs.

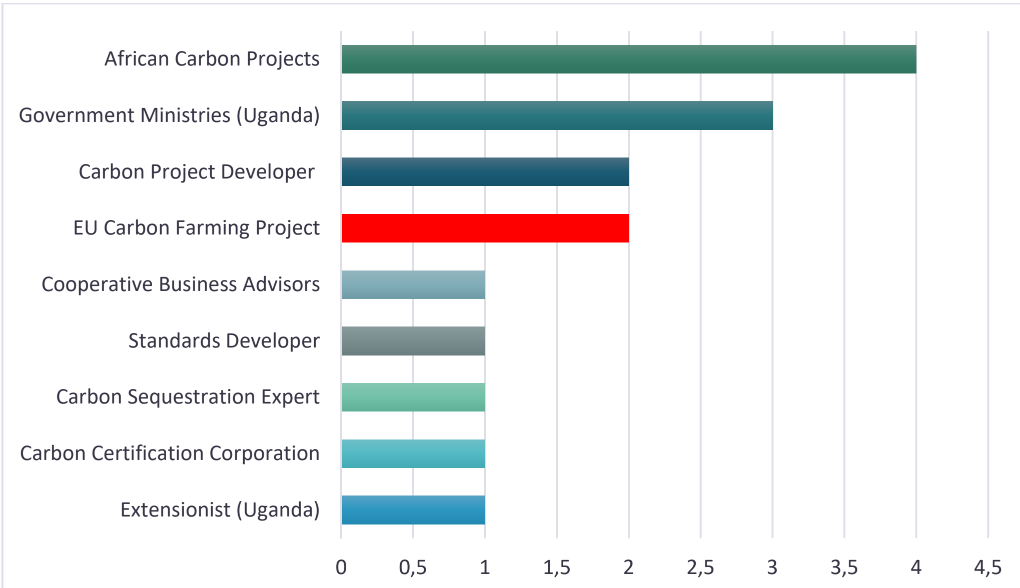
Figure 17: Bar chart showing cooperative respondents in the online survey



Semi-structured online interviews

Online semi-structured interviews for key informants from within Uganda and players in the International carbon markets were conducted. These were conducted via Skype, Microsoft teams, Zoom and WhatsApp. These provided generic data about some CFPs and more in-depth data about CCSs, standards, methodologies, entry requirements and risks.

Figure 18: Bar chart showing key Informants involved in online interviews



3.5 Data analysis

Cooperatives online survey was clustered according to 1) client status (Agriterra client and non Agriterra client cooperatives), 2) arable and perennial crop value chains and 3) region for analysis. Descriptive statistics and SPSS data analysis software was used to analyse quantitative data from the online survey while qualitative data was analysed by use MS Excel and MS Word. The grounded theory was used to analyse qualitative aspects of the online questionnaire and the online interviews.

Table 10: Summary of sample size of mixed method of data collection and analysis tools

Survey	*n*	*Percent*	*Analysis tool*
Agriterra cooperatives	*15*	*53.6%*	*SPSS & MS Excel*
Non Agriterra cooperatives	*13*	*46.4%*	
Sub Total	*28*	*100%*	
Interviews			
Uganda	*6*	*40%*	*MS word and MS Excel*
International	*9*	*60%*	
Sub Total	*15*	*100%*	

Carbon farming practices

An extensive desk study was conducted to discover evidence of CFPs from literature in various agroecological zones and contexts. The identified CFPs were then grouped according to OFPs, CoFPs, IFPs and CCPs. These were used in the online survey filled by cooperative representatives to discover which and how many practices and combinations are practiced. The economic and ecological effects were also adopted from literature and used to direct responses during the survey for ease of analysis. Four economic variables (yield, input use, income and profit) and six ecosystem service variables (carbon sequestration, soil quality, water holding capacity, pollination, biodiversity, pest and disease control) were the target of this research. Trade-offs data was qualitatively gathered inform of farmer challenges in implementing CFPs and categorised into economic and ecological, ranked, analysed and benchmarked with trade-offs from literature. Additional data from interviews was incorporated into already identified practices for comparison and contrasting. Rosa-Schleich et al., 2019's criteria to display high-low relationship between economic and ecological effects was used to identify trade-offs.

Carbon credit schemes

An extensive desk study was conducted to discover evidence of general CCSs from literature. These were then categorised into compliance and voluntary and analysed according to CFP relevance and suitability. Since CCSs are also referred to as standards, only CFP relevant methodologies were selected from standards websites and presented. Entry requirements and risks involved were retrieved from literature and standard websites and categorised into five phases. No input from the online survey was acquired under this section hence most input was from online interviews. Data from these interviews was coded via open, axial and selective criteria. The findings were then benchmarked with literature and incorporated in the categorised phases.

In the next section, the term 'respondents' is used to present online survey results with CFP in cooperative contexts while 'interviewees and / or key informants' are used to present online findings.

CHAPTER FOUR:

4.0 RESULTS AND FINDINGS

4.1 Respondents profiles

The objective of the study was to provide an insight in what CFPs are practised in Uganda, their economic and ecological effects, trade-offs while highlighting CFP agricultural related and specific CCSs, standards methodologies, entry requirements and risks involved.

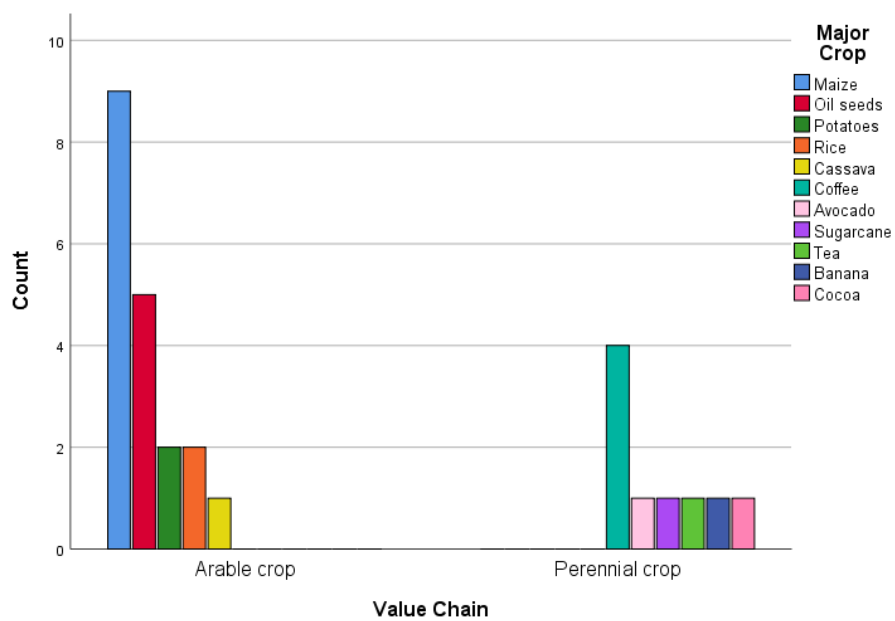
An online survey was designed and disseminated to cooperatives to mainly gain an exploratory view of the practised CFPs, their ecological and economic effects as well as trade-offs amongst cooperatives. Respondents came from 19 districts in the country across the 5 regions. Majority of the respondents were from the eastern region and majority of the respondents were Agriterra clients (*table 11*). Most respondents were actors in arable crop value chains and maize was the most grown major crop (*figure. 19).*

Table 11: Number of respondents by client status, region and value chain

			Region of the Cooperative					
		Total	*North*	*West*	*East*	*West*	*Southwest*	*Central*
		n	*n*	*n*	*n*	*n*	*n*	*n*
Client status	*Agriterra Client*	*15*	*3*	*1*	*5*	*3*	*2*	*1*
	Non Agriterra Client	*13*	*1*	*0*	*4*	*5*	*3*	*0*
Value Chain	*Arable crop*	*19*	*4*	*1*	*8*	*3*	*3*	*0*
	Perennial crop	*9*	*0*	*0*	*1*	*5*	*2*	*1*

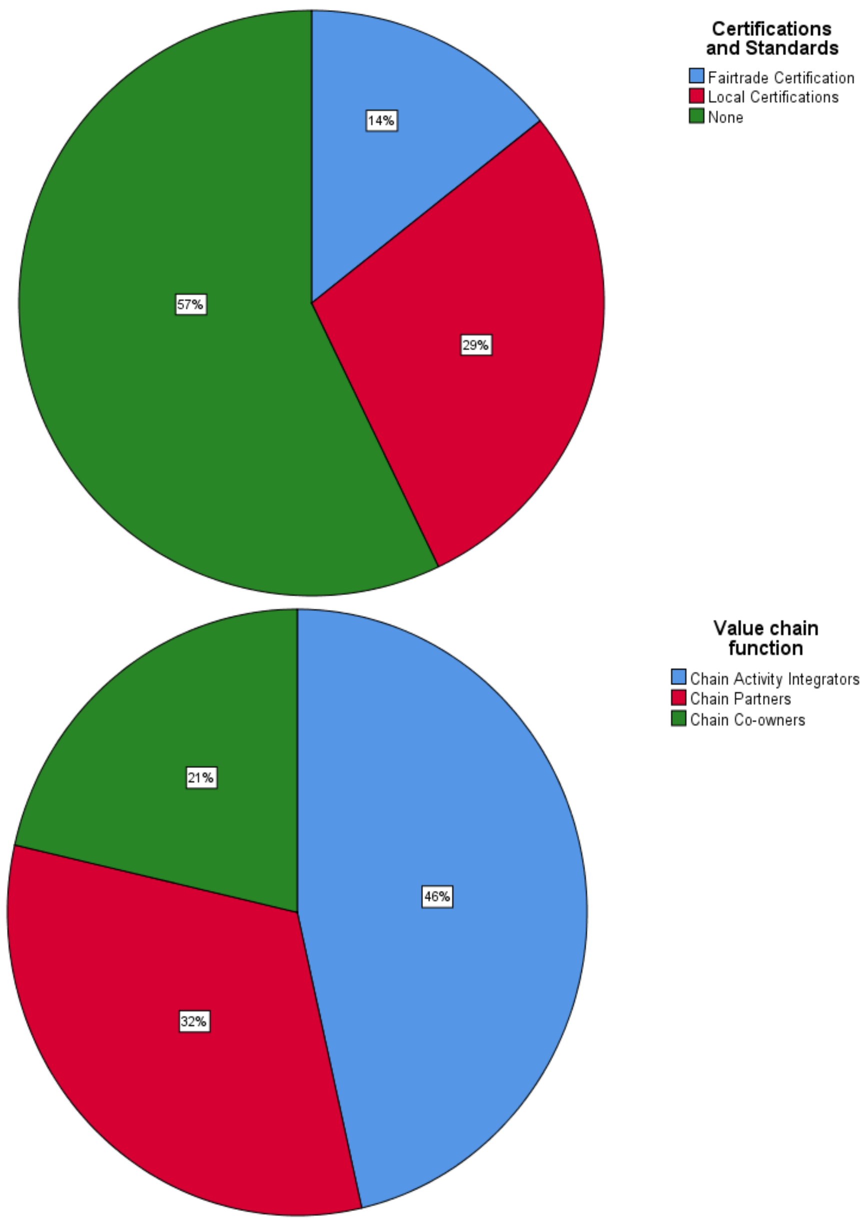
n. = number of respondents

Figure 19: Respondents by region and value chain



In addition, majority of the respondents reported that they were not certified by either local standards such as Uganda National Bureau of Standards (UNBS) and international labels like fair trade while the minority had the fair-trade certification and local certifications respectively (*figure 20).* Majority of the respondents reported that their cooperatives are involved in input provision, production, collection and trade only (chain activity integrators). These were followed by those involved in all prior chain activities but are also involved in processing and value addition (chain partners). The minority reported involved in exporting and reaching the final consumer in the chain (chain co-owners) (*figure 20*).

Figure 20: Respondents by certifications and value chain function



4.2 Carbon Farming Practices

Results of the online survey revealed that 50% of the respondents were aware of the term carbon farming, 46% reported that they were not and 4% were not sure. The following sections present an overview of what CFPs are practised by respondents with insights from some key informant interviews.

4.2.1 Organic Farming Practices

Among the OFPs examined in the study; (compost application, manure application and biochar), the results show that an equal majority of the respondents practice at least one OFP while and equal minority also reported that they practice all three OFPs and none of the them respectively.(*figure 21*) The most implemented OFPs by the respondents was compost application *(figure 21).* Interviewees 5 and 14 only mentioned the use of compost while interviewees 6 and 12 only mentioned the use of manure under this category. Compost and manure combination as used by most respondents also was advanced by interviewees 1 and 8 but findings show that biochar application was not mentioned by any interviewee. *Table 12* shows some variances in the number of OFPs applied by respondents although these could not be tested statistically due to the small dataset in most clusters.

Figure 21: Number of practiced Organic Farming Practices and ranking by respondents

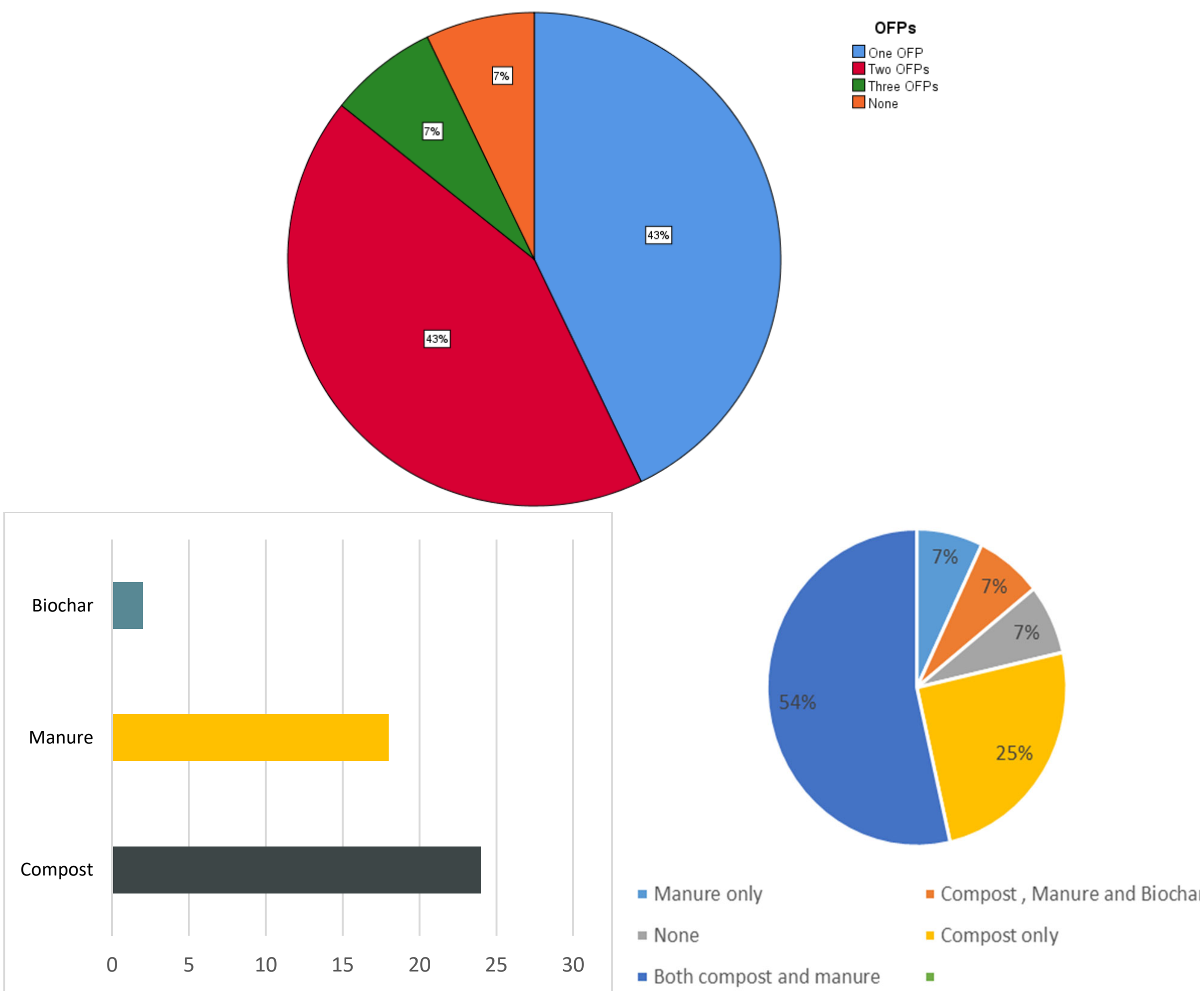


Table 12: Summary of applied Organic Farming Practices among respondents per cluster

		Number of Organic Farming Practices by respondents				
		Total	*One OFP*	*Two OFPs*	*Three OFPs*	*None*
		n	*n*	*n*	*n*	*n*
Agriterra Vs Non	*Agriterra Client*	*15*	*6*	*6*	*1*	*2*
Agriterra client	*Non Agriterra*	*13*	*6*	*6*	*1*	*0*
Value Chain	*Arable crop*	*19*	*9*	*7*	*1*	*2*
	Perennial crop	*9*	*3*	*5*	*1*	*0*
Region of the	*Northern*	*4*	*0*	*4*	*0*	*0*
Cooperative	*West Nile*	*1*	*1*	*0*	*0*	*0*
	Eastern	*9*	*5*	*2*	*1*	*1*
	Western	*8*	*1*	*6*	*0*	*1*
	Southwestern	*5*	*5*	*0*	*0*	*0*
	Central	*1*	*0*	*0*	*1*	*0*

n. = number of respondents

4.2.2 Economic and ecological effects and trade-offs

Ecologically, improved soil quality in terms of fertility was the most reported effect of these OFPs among the ecosystem services reported. Other reported effects were improved water holding capacity, enhanced microbial activity by natural organisms, enhanced pest, disease and weed control However, biodiversity, pollination services and carbon sequestration were not mentioned by any respondent in this category of CFPs. On the economic side, improved yield was the most reported effect of OFPs reported by respondents' farmers followed by increased profitability as a result of improved incomes and reduced use of other inputs. A tabular qualitative categorization of the reported ecological and economic effects and trade-offs by respondents involved in the application of OFPs in the survey reveals that the most reported effects are economic while trade-offs reported strike a balance (*table* 13).

Table 13: Summary and ranking of Organic Farming Practices economic and ecological effects and trade-offs

Effects				**Trade-offs**			
Ecological	*n*	*Economic*	*n*	*Ecological*	*n*	*Economic*	*n*
Improved soil quality	*16*	*Improved yield*	*17*	*Knowledge and adequacy of right amounts and mixtures*	*9*	*Access, purchase cost, transportation &, hectic, bulk of amendments*	*18*
Enhanced water-holding capacity	*5*	*Increased profits*	*6*	*Long decomposition time*	*7*		
Increased natural organisms	*3*	*Improved incomes*	*5*	*Harbor pests*	*2*		
Better pests, weeds, disease control	*3*	*Reduced input use*	*2*				
Total	***27***		***30***		***18***		***18***

n. = Frequency of effect among all respondents

4.2.3 Conservation Farming Practices

Amongst the CoFPs examined in the study; (no / reduced tillage, crops residues, crop rotations and cover crops, majority of the respondents were at least applying two CoFPs while the minority practice only one CoFP. (*figure 22*) While the most implemented CoFP was crop rotation, majority of the respondents (32%) were using all the CoFPS combined. Submissions from six key informants also reveal that CoFPs were applied in combinations and no single interviewee mentioned only one CoFP. *Table 14* shows some variances in the number of CoFPs applied by respondents although these could not be tested statistically due to the small dataset in most clusters.

Figure 22: Number of practiced CoFPs and ranking by respondents

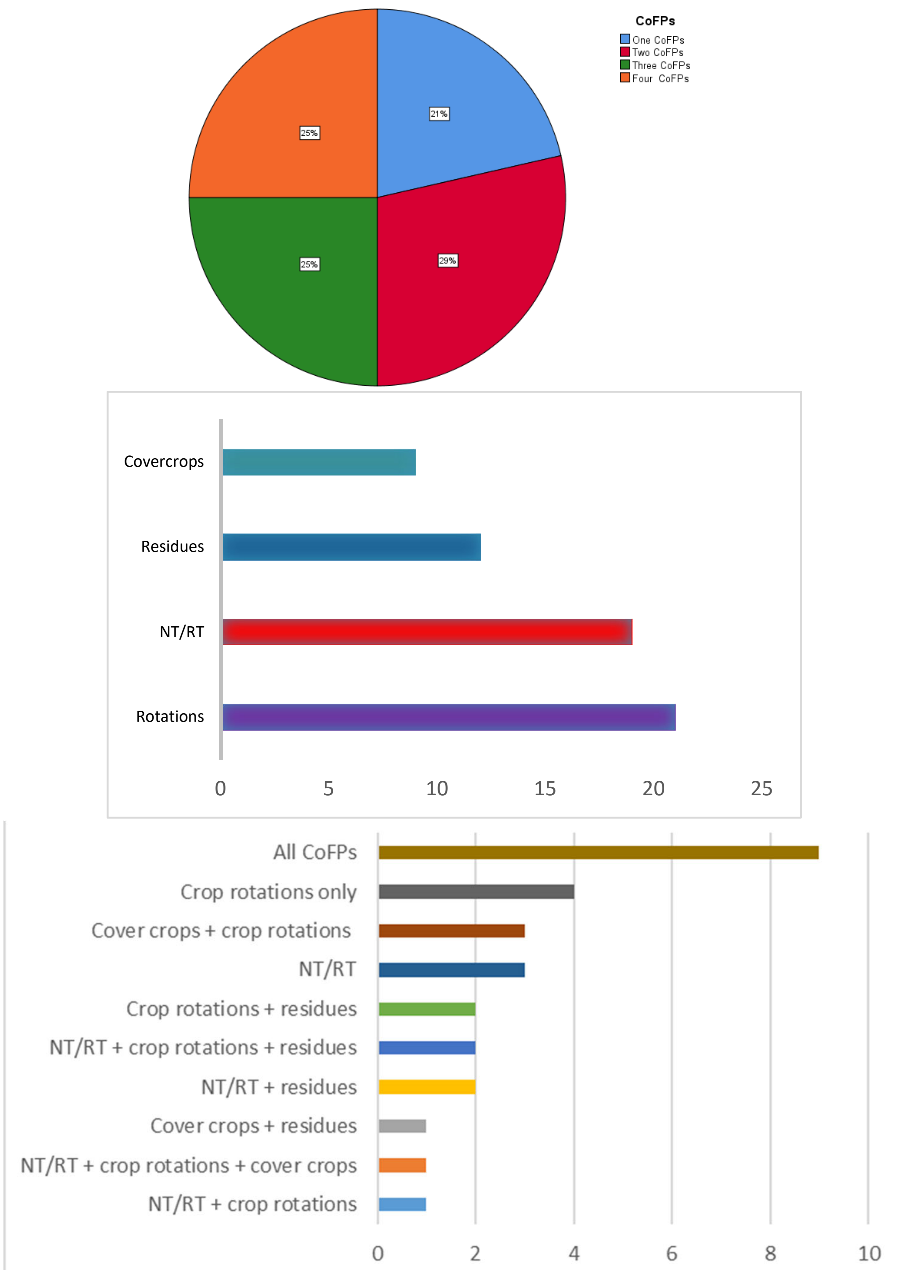


Table 14: Summary of applied Conservation Farming Practices among respondents per cluster

		CoFPs					
		Total	*One CoFPs*	*Two CoFPs*	*Three CoFPs*	*Four CoFPs*	*None*
		n	*n*	*n*	*n*	*n*	*n*
Agriterra Vs Non Agriterra client cooperative	*Agriterra Client*	*15*	*4*	*3*	*4*	*4*	*0*
	Non Agriterra Client	*13*	*2*	*5*	*3*	*3*	*0*
Value Chain	*Arable crop*	*19*	*4*	*6*	*5*	*4*	*0*
	Perennial crop	*9*	*2*	*2*	*2*	*3*	*0*
Region of the Cooperative	*Northern*	*4*	*1*	*0*	*2*	*1*	*0*
	West Nile	*1*	*0*	*1*	*0*	*0*	*0*
	Eastern	*9*	*2*	*2*	*1*	*4*	*0*
	Western	*8*	*1*	*3*	*3*	*1*	*0*
	Southwestern	*5*	*2*	*2*	*1*	*0*	*0*
	Central	*1*	*0*	*0*	*0*	*1*	*0*

n. = number of respondents

4.2.4 Economic and ecological effects and trade-offs

Ecologically, improved soil quality was the most reported effect of CoFPs among the ecosystem services followed by improved water holding capacity and better pest, disease and weed control. Under this category of CFPs, biodiversity, pollination services and carbon sequestration services were not mentioned by any respondent. Economically, improved yield improvement was the highest reported effect of CoFPs followed by reduced usage of other inputs while profitability and improved incomes were the least mentioned effects of the application of CoFPs respectively. This is the only CFP category in which low yield was reported. Hence ecological effects outweighed economic effects while economic trade-offs outweighed ecological trade-offs (*table 15*).

Table 15: Summary and ranking of Conservation Farming Practices economic and ecological effects and trade-offs

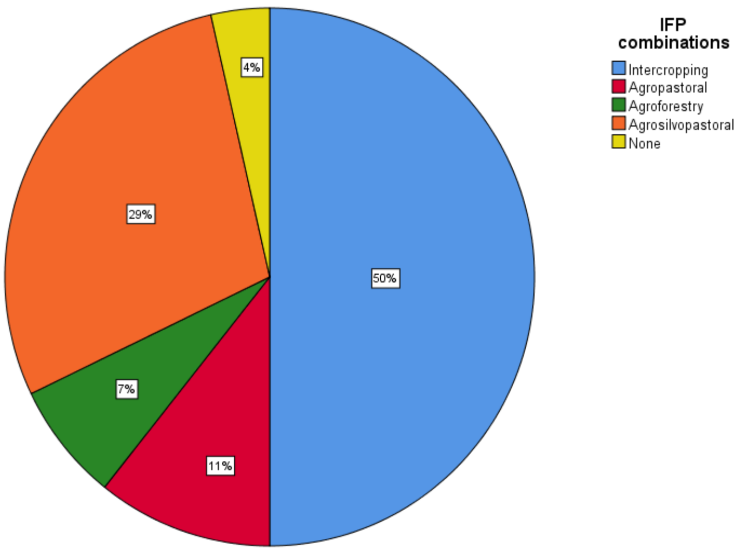
Effects				***Trade-offs***			
Ecological	*n*	*Economic*	*n*	*Ecological*	*n*	*Economic*	*n*
Improved soil quality	*12*	*Improved yield*	*12*	*Land availability / shortage*	*7*	*Capital, costs & availability of materials & Knowledge and skills*	*8*
Enhanced water-holding capacity	*6*	*Reduced input use*	*4*	*Right crop rotations varieties, pathogens, harbour pests,*	*3*	*Time consuming, labour intensity, shortage, and costs*	*4*
Better pests, weeds, disease control	*5*	*Increased profits*	*2*			*Low yield*	*3*
		Improved incomes	*2*				
Total	***23***		***20***		***10***		***15***

n. = Frequency of effect among all respondents

4.2.5 Integrated Farming Practices

IFPs are a common farming system amongst most of the respondents. Intercropping was the most reported IFP (50%) while agroforestry was the least reported IFP (*figure 23*). Interviewees 1, 12 and 13 also mentioned mixed farming systems as common IFPs studied under this CFP dimension. However, 10 key informants emphasised agroforestry and planting of trees as a CFP under this dimension although it does not appeal to most respondents as it does to one key informant who said: "*We are not going to plant trees because that's a little bit too much for us at this moment, and it's also not very profitable*". Table 16 shows some variances in the IFPs combinations applied although these could not be tested statistically due to the small dataset in most clusters.

Figure 23: Ranking of practiced Integrated Farming Practices by respondents



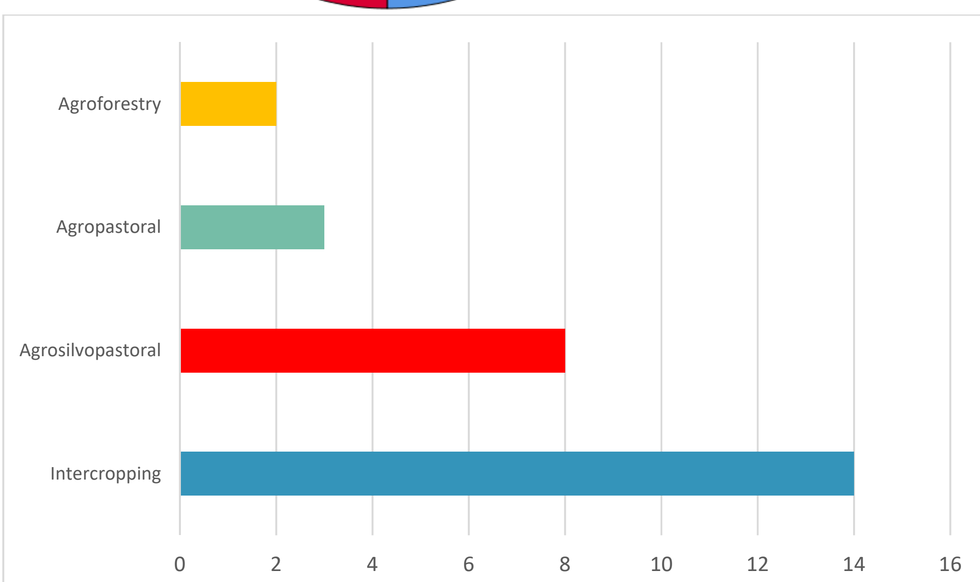


Table 16: Summary of applied Integrated Farming Practices among respondents per cluster

			IFP combinations				
		Total	*Intercropping*	*Agropastoral*	*Agroforestry*	*Agrosilvopastoral*	*None*
		n	*n*	*n*	*n*	*n*	
Agriterra Vs Non Agriterra client cooperative	*Agriterra Client*	*15*	*8*	*1*	*1*	*5*	*0*
	Non Agriterra Client	*13*	*6*	*2*	*1*	*3*	*1*
Value Chain	*Arable crop*	*19*	*11*	*2*	*1*	*4*	*1*
	Perennial crop	*9*	*3*	*1*	*1*	*4*	*0*
Region of the Cooperative	*Northern*	*4*	*1*	*0*	*0*	*3*	*0*
	West Nile	*1*	*1*	*0*	*0*	*0*	*0*
	Eastern	*9*	*4*	*1*	*1*	*2*	*1*
	Western	*8*	*3*	*2*	*1*	*2*	*0*
	Southwestern	*5*	*5*	*0*	*0*	*0*	*0*
	Central	*1*	*0*	*0*	*0*	*1*	*0*

4.2.6 Economic and ecological effects and trade-offs

Improved soil quality was the most reported ecosystem service followed by enhanced water hold capacity and better pests, weeds, disease control in relation to the ecological effects of IFPs assessed. Other ecosystem services such carbon sequestration, pollination services, and biodiversity were still not mentioned by any respondent. Economically, improved yield as a result of diversification under IFPs recorded the highest number of respondents while reduced inputs due to interdependence of the farming system activities were mentioned second, followed by improved incomes and increased profitability was the least mentioned. *Table 17* shows that the most reported effects of IFPs are more economic rather than ecological and the same applies to the trade-offs.

Table 17: Summary and ranking of Integrated Farming Practices economic and ecological effects and trade-offs

Effects				***Trade-offs***			
Ecological	*n*	*Economic*	*n*	*Ecological*	*n*	*Economic*	*n*
Improved soil quality	*3*	*Improved yield*	*13*	*Soil rest, fertility loss, nutrient competition,*	*5*	*Management, time consuming, costly, high labour, land, capital*	*10*
Enhanced water-holding capacity	*1*	*Reduced input use*	*6*	*Pests, animal eat up crops*	*4*	*Low yield*	*2*
Better pests, weeds, disease control	*1*	*Improved incomes*	*4*			*Knowledge, skills, Not common system*	*3*
		Increased profits	*2*				
Total	***5***		***23***		***9***		***15***

n. = Frequency of effect among all respondents

General CFP ecological and effects were highlighted by interviewee 6 who reported that: "soil quality (health) is improved, water retention is high, less prone to erosion less floods, run off, water services, salitation, less use of chemicals, increased biodiversity, increased productivity, increased carbon sequestration, is a consequence of more carbon in soil". It was also common for interviewees 8, 13 and 14 to suggest soil quality among the ecological effects as yield was the most mentioned economic effect by interviewees 2, 6, 13, 14 and 15 while reduced input usage came second.

4.2.7 Crosscutting practices

As a way of improving soil fertility, 46.4% of the respondents reported that they use both organic and inorganic fertilisers while 53.6% of the respondents reported that they mostly use chemical methods for pest control, 60.7% of the respondents reported that the use hand weeding, 78.6% of the respondents reported that they only on rainfall for their crops (*table 18)*

Table 18: Summary and ranking of cross cutting practices

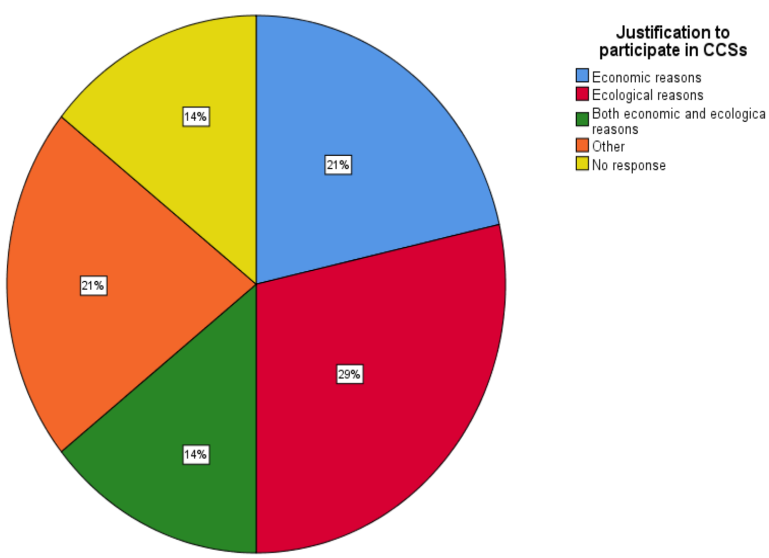
Nutrient Management	***n***	***Pest Management***	***n***	***Weed Management***	***n***	***Water Management***	***n***
Both organic and inorganic fertilisers	*13*	*Chemical control*	*15*	*Hand weeding*	*17*	*Only rainfall*	*22*
Organic fertilisers	*7*	*Integrated Pest Management*	*8*	*Mechanical weeding*	*6*	*Both irrigation and rainfall*	*6*
Inorganic fertilisers	*6*	*Cultural control*	*3*	*Herbicides*	*3*		
Recycling crop residues	*2*	*No control*	*2*	*Mulching*	*2*		
Total	***28***		***28***		***28***		***28***

n. = Frequency of CCP among all respondents

4.3 Carbon Credit Schemes

In the survey, majority of the respondents showed awareness of the term carbon credits and were however interested in participating in CCSs. The highest motivation for the respondents who expressed willingness to participate in CCS was mainly because of the ecological effects associated with CFPs followed by their economic effects (*figure 24)* while others were interested in more knowledge and support.

Figure 24: Respondent motivation and justification to participate in carbon farming and carbon credit schemes



4.3.1 Compliance and Voluntary CCSs

Among the CCS dimensions investigated in this study such as; compliance and voluntary schemes, findings from most key informants suggest that the voluntary schemes are the most compatible schemes with carbon farming. Interviewee 9 is quoted to have said;

" *Voluntary markets are the main markets where you can develop credits that originate from agricultural projects, there are no compliance markets in the world that would accept carbon farming credit units from East Africa, except the voluntary market; The voluntary markets have some flexibility in the rules about where the units come from*".

This notion was supported by interviewees 1, 2, 6, 7, 10 and 14 in relation to the CDM which is the major compliance scheme certifying only forestry projects whose future is uncertain (Interviewee, 11) because of the Paris Agreement.

4.3.2 CCS Standards and Methodologies

The Verified Carbon Standard (VCS) (now Verra) and Gold Standard are the most used voluntary standards (Interviewee, 2). Interviewee 6 also noted that, "Verra, Gold Standard and American Carbon Registry (ACR) standards focus on changes in soil carbon stocks and are agricultural related". The only mentioned carbon farming related methodologies were SALM (Interviewee 14) and IALM (Interviewee 4) under Verra while the Gold Standard low tillage methodology was mentioned by Interviewee 11 However, Interviewee 14 expounded that in some projects a blend of methodologies is possible for different activities which may not be accounted for in a given methodology. "Methodologies are also developed by third parties and reviewed by us and are made available for adoption" (Interviewee, 4).

4.3.3 Entry requirements

Findings from most key informants revealed that participation of cooperatives in CCS requires projects development. These requirements were arranged into four major themes which include the pre project development phase, the development validation and registration phase, the monitoring reporting and verification phase and the carbon credit issuance phase.

The pre development phase requires a project idea (Interviewee 5), area of interest (Interviewee 6) and stakeholder mapping such as local beneficiaries with motivation and some knowledge (interviewees 1 & 14) but also with international quality certifications such as Fairtrade, with accountable group governance structures (Interviewee, 2) and local leadership support (Interviewees 8, 11 & 14). Government agencies are critical at this since they have set own emission reduction targets but are often stuck at implementation (Interviewee, 1) The role of leadership was emphasized mostly by interviewee 8 who said,

"*I'm the president of the branch of the farmers' union, that's how I go to the information and I spread the information to all our members*"

Another striking submission about stakeholders under this phase was fronted by Interviewee 7 who suggested *in setting* as a way of decarbonising crop value chains through tracking of products and actors from African producers to the global retailers and consumers in a bottom – up approach. Interviewee 1 & 2 suggested network and partnerships formation that bring together corporations both national and transnational interested in offsetting or in setting. At this stage, actors and companies in these value chains with emission reduction goals and SDG orientation can be contacted as potential investors and/or buyers buy discovering their needs and Memoranda of Understandings

(MOU) (Interviewee, 1 & 10). This phase also requires a short- or medium-term pilot to validate studies CFP interventions identified from scientific literature (Interviewee, 1) under any different agroecological zones from success projects and study areas (Interviewee, 14). Project developers are required during this phase and might be used as either consultants for development, validation and registration or as project partners involved in all phases of the project lifecycle (interviewee 5).

The development, validation and registration phase requires secured funds which sometimes range between 25,000 and 50,000 Euros (Interviewee 2 & 3) depending on the project developer contracted. A sample cost break down for a specific developer is annex 2. This phase also requires studies such as a baseline study (Interviewee 2 & 11), cost benefit assessment (Interviewee 4), carbon stocks assessment (Interviewee 6), technical and financial feasibility (Interviewee 3) and at least 3 SDGs impact assessment (Interviewee 4) or socio-economic assessment (Interviewee 6). In addition, this phase requires standard and methodology adoption (Interviewee 1, 2, 3 & 6), carbon credit volume estimations, quantification mechanisms and price negotiations with buyers (Interviewee 4 & 11). Project documentation (Interviewee 1, 2, 3, & 5), validation (Interviewee 5, 6 & 11), registration (Interviewee 2, 5 & 11) and transfer of carbon rights (Interviewee 11) to communities are the last requirements for this phase.

The project management and implementation phase requires engagement of project stakeholders and formation of a council of representatives (investors, the farmers, intermediary organization) (Interviewee 3). This phase also requires working with local supporters under a well project administration processes (Interviewee, 2) recruiting, contracting, training farmers in project intervention activities (Interviewee, 14). This is the longest phase of the entire project hence requires deep motivation for the farmers (interviewee, 1)

The monitoring, verification and reporting phase requires proper monitoring (Interviewee 2, 5, 6 & 11), verification (Interviewee 5) by third parties DoE's or VVBs (Interviewee, 2) and periodical reporting (Interviewee 1 & 11). This phase determines whether credits were really generated according to adopted standard and methodologies before issuance. Interviewee 4 asserted that,

"*Part of each methodology is a verification component carried out by third party auditors called Validation Verification Bodies (VVBs) the project developer contracts the VVB to do the audit or to demonstrate that the project is following the rules and equations formula applied correctly, who conduct field visits, collect samples and conduct interviews*"

DOE / VVB or auditor selection at this phase depends on either the standard adopted and/or the size of the project (Interviewee, 11). This phase also preparing and orienting beneficiaries for data collection and self-monitoring (Interviewee 2 & 14) by provision of forms and cellular devices for data upload (Interviewee 14) while maintaining field monitoring by both project and government extensionists (Interviewee 14).

The carbon credit issuance phase involves the credit issuance by the respective standards (Interviewee 5), entered into a registry account with a unique serial number, date, country (Interviewee 3 & 11), commercialised through brokerage or retail after which they retired and claimed (Interviewee 3 & 11). At this stage, buyers are interested in the origin of the credits generated with people component and nice stories (Interviewee 2 & 9) although some buyers are just interested in buying credits not the cost of producing them (Interviewee, 5).

4.3.4 Risks

Findings revealed that the various risks along the different phases of project development presented in the previous section as shown in table 19;

Table 19: Summary of carbon credit schemes risks findings

Phase	Risk	Source
Pre-Project Development (PPD)	Uncertain fate of international compliance schemes bound by treaties like the Kyoto protocols CDM and the Paris agreement	Interviewee 11
	Short term money requirements of farmers	Interviewee 1 & 5
	Uncertainty of revenue generation and institutional risk	Interviewee 6
	Entrepreneurial risk, behavioural change, financial risk	Interviewee 2
	Land tenure rights	Interviewee 4
	Other faming systems emission factors	Interview 8
Development, Validation and Registration (DVR)	Additionalities and restraining certain community rights	Interviewee 6
Project Management and Implementation (PMI)	Credits production risk and natural calamities	Interviewee 3, 5 & 6
	Annual investment risk	Interviewee 1
Monitoring and Reporting and Verification (MRV)	Labor and time intensity	Interviewee 3
	Long term and costly verification	Interviewee 9
Carbon Credit Issuance (CCI)	No credit issuance and certification	Interviewee 5 & 2
	Uncertain prices	Interviewee 7
	Fluctuating demand of buyers in voluntary markets	Interviewee 9
	Changes in the CCS like CDM	Interviewee 5

CHAPTER FIVE:

5.0 DISCUSSION

5.1 Carbon Farming Practices

The study objective was to get an overall representation of what CFPs are through data collection methods adopted. An extensive desk study, a survey with cooperative representatives and additional data from key informant interviews were used to unravel the first main question. The results provide a synthesis of an aggregated number of CFPs with cross-examination of their ecological and economic effects as well as trade-offs amongst cooperatives because they had no working knowledge about CCS despite some little awareness and interest to participate. With my approach, it was not possible to live among respondents and build rapport through interaction and observation due to the COVID-19 pandemic. As a result, in-depth thoroughness and people-centric components were traded-off to general results from the respondents. These results provide a general ground insight by cooperative representatives who are farmers involved in the day to day farm field operations of their members. The choice of the study clusters (Agriterra vs non-Agriterra client cooperatives, arable and perennial value chains and region) was to allow cross-cluster analysis through comparing the CFP dimensions studied. These results lack verifiable indicators from smallholder farmers in terms of records and experiments to establish real baselines and actual ecological and economic effects and trade-offs on the ground due to the data collection method adopted amidst the corona pandemic. Given the large scope of this study, it would have necessitated longer periods of study like two cultivation seasons with more assessment methods such as laboratory experiments, observations with ex-ante and post ante data to quantify these effects establish trade-off relations with precision.

5.1.1 Organic Farming Practices

Compost as the most applied OFP by respondents conforms Al-Sari *et al.,* (2018) and its combination with manure also resonates with Van der Wurff *et al.,* (2016) who asserted that most composts are made of plant residues and manure as well as Nguyen *et al.,* (2013) who suggested a mixture of organic amendments. OFP application by a large majority of respondents could also be due to local availability of cheap organic amendments Tugume *et al.,* (2019). Such as a study context, however, was in relation costly commercial fertilisers versus the huge amounts of dumped manures in the central region which had the least number of respondents in this study. As a farmer, I used to adopt the use of new farming practices from fellow farmers without doubt by mixing whatever types and applying in the farm. This practice is still common and it’s still not clear in what types, composition and volumes of these amendments are used to ascertain whether they do more good than harm. Biochar has been widely documented including studies with Uganda (Roobroeck *et al.,* 2019) although implementation is still limited as shown in the results probably due to limited awareness, competing uses for crop residues yet it can be easily produced locally (Mekuria & Noble, 2013). These results also portray that some Agriterra clients are involved in conventional or ecologically destructive farming practises since some implement none of the OFPs. More so, this study has witnessed respondents mixing the use of both OFP amendments and other chemical inputs. Interventions to abate in the transition towards OFP application by Agriterra could target such clients while advancing to cooperatives that apply only one OFP. Cooperatives in arable crop value chains showed a high OFP adoption rate than in perennial crop value chains. The high number of cooperatives in arable crop values shows that farmers grow more food crops and links to food security in the various areas. This could also be due to various country specific studies with focus on arable crops like Komakech *et al.,* (2015)’s maize study and Bua *et al.,* (2017)’s onion study although it’s not clear how such scientific studies have been promoted to be adopted in local contexts. In order to promote sustainable through OFPs, by Agriterra and the community of practise, this study reveals that arable value chains appeal most to small holders given the nature and quick rate of social and economic returns they envision to attain.

Results showed that respondents are more aware about soil fertility OFP effect, (Seitz et al., (2018), Liu *et al.,* (2012), Van der Wurff *et al.,* (2016), Conant (2011), Lim *et al.,* (2014) Swati & Hait, (2018) and Tugume *et al.,* (2019), improved water holding capacity conforming to Delgado *et al.,* (2011), enhanced microbial activity by natural organisms, enhanced pest, disease and weed control as argued by Koplowicz, (2019). Most importantly, these three ecological effects also dominated in the literature section of this study. However, the disconnect of respondents from other ecosystem services like biodiversity and carbon sequestration seems worrying since they are of great significance in carbon farming and GWP potential. This disconnect could arise from the invisibility and intangibility of the biodiversity and carbon sequestration and potentially risk cropland expansion into forests which highly threatens biodiversity (Morán-Ordóñez *et al.,* 2017). Since economic parameters appeal most to farmers, improved yield (Komakech *et al.,* 2015: Jindo *et al.,* 2016), increased profitability (Müller-lindenlauf, 2009) as a result of improved incomes and reduced use of other inputs (Biala, 2011) were reported simultaneously by the respondents. However, although OFPs often lead to Nitrogen loss during decomposition, these results contradict most studies that suggest reduced yield (Wittwer *et al.,* 2017). More so, OFPs are quite expensive to implement but it's not clear as to why trade-off results were balanced in this study.

5.1.2 Conservation Farming Practices

A larger percentage of respondents implement both all CoFPs combined which provides opportunities for increased ecosystem service delivery and synergies (Palm *et al.,* 2014). This survey shows that crop rotations as the most implemented CoFP (*figure* 22) which quite contradicts with what I have practiced as a farmer and witnessed in most farms in the country where same crops are grown on the same piece of land for long periods of time. This same observation was made by an Interviewee 8 during his visit to Uganda although rotations can be possible when respondents involved in polycultures implement intercropping and cover crops as suggested by McDaniel *et al.,* (2014). The low use of crop residues by respondents is justified in residue burning while preparing farmland as stated by Interviewee 13. The results also show that most Agriterra clients implement the most CoFPs while some still implement only one CoFP which is likely to limit the benefits accruing from CoFP combination as suggested by Sanaullah *et al.,* (2019). The results also provide promising progress in the number of CoFPs implemented across the east and western regions compared to other regions.

The results of this study also confirm that CoFPs ecosystem services enhancement by Lee *et al.,* (2019) such as soil fertility improvement (Rosa-Schleich *et al.,* 2019), water retention capacity (García-Tejero et al., 2020) weed pest and disease control (Srinivasarao *et al.,* 2014). These results depict that the three mentioned ecosystem services are directly tangible and related to output which results into economic viability inform of reported yield improvement (Lee et al., 2019), increased profitability (Kiran et al., 2020) and reduced input usage (Sharma *et al.,* 2018). Chances of yield and income maximization in higher when CoFPs are jointly practiced (Tambo & Mockshell, 2018) as this most respondents in this study revealed. Realisation of more economic requires more economic inputs for CoFP implementation. However, reduced yield was reported in this particular CFP dimension among all CFPs. More so, CFP yield increment is claimed to be in form of small percentages that could compromise food security in the long run (Corbeels et al, 2020). Thus, this study confirms as to why the most reported trade-offs were economic compared to ecological. This means that for effect CFP transition, carbon sequestration roles need to be a norm at farm level amongst farmers .

5.1.3 Integrated Farming Practices

The study further revealed that most respondents are involved in mixed farming systems and mostly practise the intercropping combination (*figure 12*). Agroforestry was fronted by more interviewees than respondents. This big difference is probably due to the perceived non profitability of agroforestry systems by farmers on arable lands (Interview, 8) coupled with small pieces of owned land. More so, the fact that respondents are largely involved in arable crop value chains greatly underpins this intercropping IFP wide application. This result however contradicts with Peterson *et al.,* (2020) and Interviewee 14 who noted that agropastoral combinations are a default system among small holder settings. This assertion stands to resonate with own experience and observation as it is a common practice to find small number of livestock, poultry, cows, goats, rabbits, pigs, fish among others. However, most of these livestock units are not commercial. It is also quite interesting that the agrosilvopastoral IFP was reported by most Agriterra client cooperatives. This presents an opportunity for the community of practice to promote IFPs.

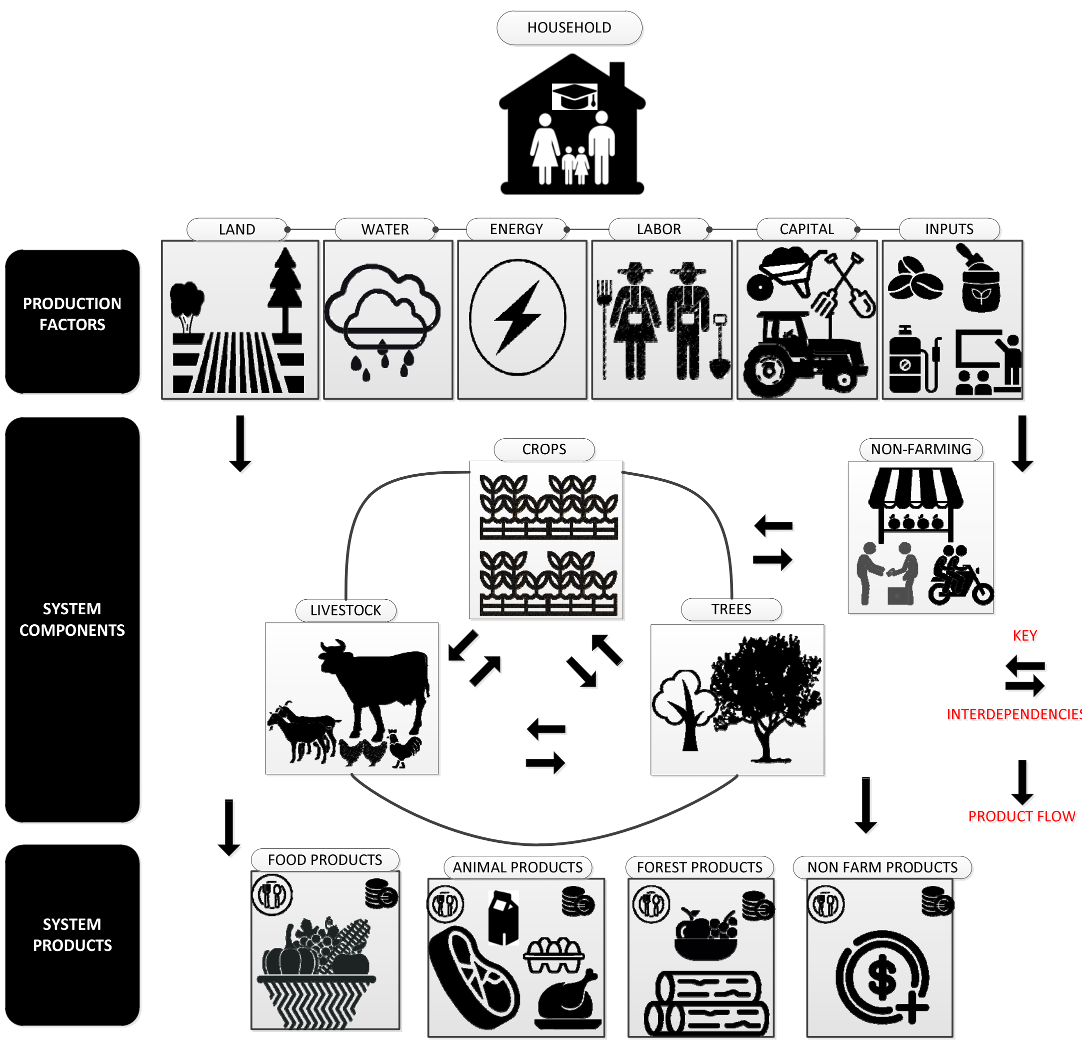
The economic effects of IFPs clearly outweighed the ecological effects in this study inform of yield improvement (Liu et al., 2016: Cong et al., 2014), reduced input usage (Sánchez et al., 2016) and diversified incomes (Delgado *et al.,* 2011). 150% yield improvement as argued by Hu et al., 2015 and Interviewee 14 is attributed to intercropping as it is the case with most respondents in this study. The reduced input usage is due to the interdependency of the farming systems and shareable inputs as suggested by some agropastoral respondents and Mendonça *et al.,* 2020. In as much as Delgado *et al.,* (2011) and Rao, (2007) argued improved incomes for agroforestry systems, this is not evidently appealing to most respondents as did Interviewee 8. In contrast to OFPs and CoFPs, the results show the soil fertility improvement as an outcome of intercropping with leguminous crops (Delgado *et al.,* 2011) and agrosilvopastoral combinations (Gil *et al.,* 2015). Although little responses in terms of water holding capacity and pest, disease and weed control were reported in this study in support of (Kremen & Miles, 2012), other ecosystem services were still not reported. Perceived ecological trade-offs inform of nutrient loss were reported by most respondents due to nutrient competition on the same piece of land compared to respondents in support of soil fertility improvement. This could imply that implementation of IFPs still lacks localised proof and scientific evidence for implementation in favour of ecological benefits (Reed *et al.,* 2017). The most economic trade-offs involved in IFP implementation reported in this study were in form of management complexities and high resources which connects with Gil *et al.,* 2015 & Rosa-Schleich *et al.,* 2019. More to this are the knowledge requirements reported which are in relation to a recent study conducted in Uganda (Mfitumukiza et al., 2020). No quantified indicators and compositions of the different components of the farming systems under IFP application were measured.

5.1.4 Cross cutting practices

In this study, the we adopted this category of practices due their commonality in application across the three OFP, CoFPs and IFP dimensions. It is common knowledge that any farming system can hardly survive without practices such as integrated nutrient management, irrigation and integrated pest, management and proper weed management. Majority of the respondents reported the use of both organic and inorganic fertilizers which could be a constructive and destructive practice depending on the levels at which the other is used compared to the other. In this study, respondents reported the use of compost, manure, biochar, crop residue use, intercropping, rotations which are source of organic nutrients (Srinivasarao *et al.,* 2014) with limited use of fertilisers as argued by Interviewee 16 which is promising. However, most respondents reported wide use of chemical pest and disease control methods which pose a threat to the ecosystem. At this moment in this study, the use of pesticides to acceptable levels that economically and ecologically decrease or minimise jeopardy to human health and the environment cannot be justified in as much as IPM was the second most used pest control method. The most reported weed control method in this study was hand weeding probably due to limited land sizes owned by farmers. Around two-thirds of these farmers households own less than two hectares of land (Anderson et al., 2016). More so, the lower weed prevalence by respondents who used OFPs, CoFPs and IFPs. In terms of water, Komakech *et al.,* 2015`s study showed that application of organic amendments may not yield much in absence on water for crops. The fact that most respondents rely on rainfed agriculture jeopardises the possibilities of OFP benefits hence the need for irrigation.

CFP promotion is quite labour intensive which could promote more gender inequalities since women are the most involved in farm work compared to men (Corbeels et al, 2020). This requires careful consideration for Agriterra and the community of practice before CFP promotion. As such, various production factors such as land ownership rights, water access, energy use, labour, capital and other inputs of the farming system small holder households need consideration (figure 25). However, while building on farmer awareness, motivation and already existing studies highlighted in this study and the few economic and ecosystem service studies CFP integration and combination in practise (Kanyenji et al., 2020) is likely to create more synergies of economic and ecological benefits while minimizing trade-offs (Liu et al. 2016). A cross examination of the hidden realities among households is necessary for an all-round idealistic climate smart farming system as illustrated in figure 25.

Figure 25: Illustration an idealistic carbon farming system



Source: Author's compilation

5.2 Carbon Credit Schemes

In the second part of this study is overall representation of the different CCSs through an extensive desk study and in-depth data from key informants' interviews to unravel to second main question. The results provide a synthesis of agriculture related CCSs with cross examination of their standards and applicable methodologies as well as entry requirements and risks involved. With this approach, a lot of online data was acquired and synchronized with interviewee experiences and expertise.

5.2.1 Compliance and voluntary schemes

The Kyoto Protocols CDM was the only mechanism through which developing countries could participate in emission reductions (Seeberg-Elverfeldt, 2010). However, findings have revealed the international compliance CDM mechanism is no place for carbon farming and cropland generated credits in developing countries. On this basis of argument, agricultural crop land expansion into forest cover as a global threat to biodiversity (Morán-Ordóñez *et al.,* 2017) and the high rates of global deforestation and forest fragmentation (FAO & UNEP, 2020) probably justifies why the CDMs main AFOLU component was the REDD + compared to other land use components such as crop land carbon sequestration. This justification appears to side-line carbon sequestration through agricultural carbon farming which is the backbone of many developing countries like Uganda. Foley et al., 2020 proposed climate change solutions through not only ecosystem restoration like the CDMs forestry-based projects but also shifting agricultural practices (such as CFP) as revealed by this study as a way of catalysing natural carbon capture while enabling small holder and cooperative agricultural intensification. That said, its future remains uncertain while experiencing a huge emission reduction volume decline as CDM credit producers are stuck where to sell (Ecosystem marketplace, 2019).

In addition, the above assertion holds water considering the prioritised actions and commitments for country NAMAs and NDCs respectively because forestry is the least prioritised sector in all developing country submissions while agricultural carbon sequestration is gaining tract (Afanador et al., 2017). Findings in this study revealed no responses about NAMAs as credible crediting mechanisms which raises questions about their relevance post the Paris era while most are stuck without implementation. In the NDC world, where developing countries have 186 COP parties submitted to the Paris Agreement (UNFCCC, 2020), NAMAs are doomed to stagnate although they could provide a basis for NDC emission reduction goals by parties (Afanador et al., 2017). That said, NDCs could potentially be used as a basis to develop in-country national credit schemes in order to precipitate carbon farming-based credits In light of the voluntary schemes, the results reveal that carbon farming crop land generated credits can only be traded in voluntary schemes (Seeberg-Elverfeldt, 2010). Voluntary schemes have been positioned at the helm of emission reduction trading with better prices compared to the CDM by interviewees in this study. There are critics as to whether carbon credit schemes really play role in emission reductions or keeping GHG emission in balance. However, such schemes are not entirely promoting continued emissions by corporations but also reward those that reduce their footprint. More so, as market awareness of the carbon neutrality label are gaining traction which shall force corporation to cut emission within their value and supply chains. These results have identified gaps and opportunities for in country credit schemes for both research and practice. Lessons from well-established national carbon markets provide a promising stepping block for developing countries with less reliance on uncertain international compliance and voluntary schemes.

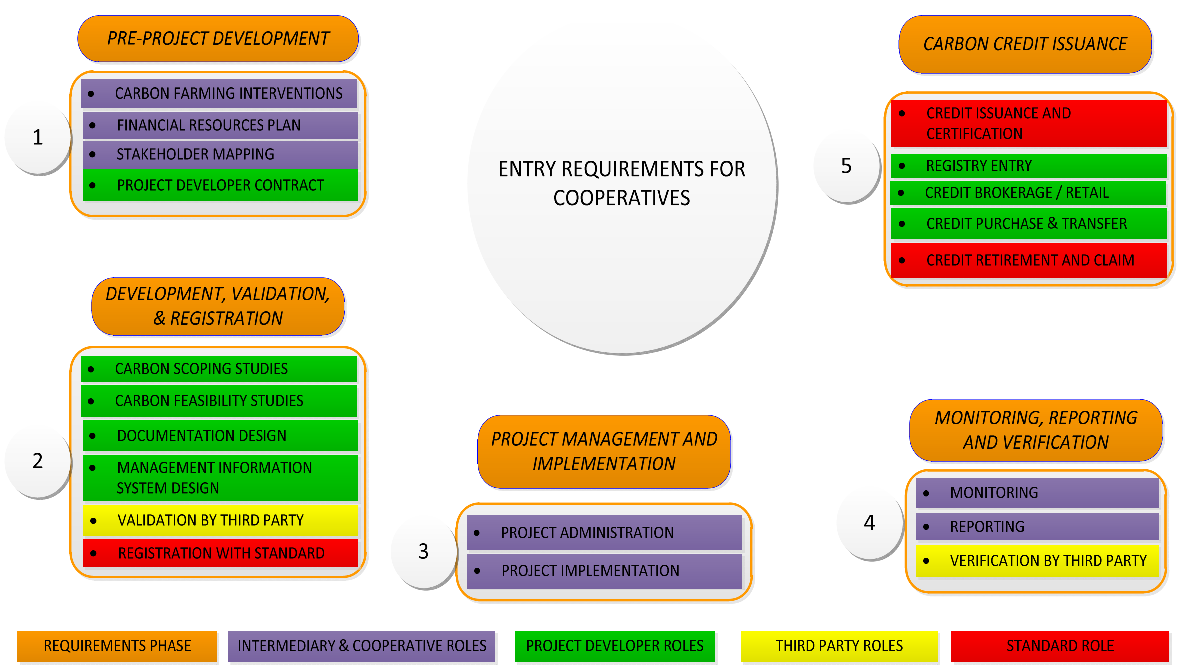
5.2.2 Standards and methodologies

The results confirm reveal that among the various compliance and voluntary standards, there is only one SALM carbon farming methodology under the Verra. Until now, the new IALM methodology is still in the pipeline which according to our interviewees is meant to attract more carbon farming related projects since the SALM methodology has gain little traction since its inception. There are possibilities of either use of blended methodologies for various CFP combinations or developing new specific methodologies which is costly in terms of time and resources. However, funders or investors such as might prefer the EU Gold standard with only one soil carbon methodology momentarily while others might prefer the US Verra with a wide variety. These conditionalities are likely to influence which methodologies are to be used. Opportunities for using blended methodologies or developing CFP specific methodologies are still on demand.

5.2.3 Entry requirements

Requirements for cooperative participation in CCSs are embedded within project development as revealed by the findings. The process of developing these projects needs considerably much time, resources and high technical expertise (Seeberg-Elverfeldt, 2010). These high-level requirements are by no means affordable to small holder farmers whose major concern is to earn a livelihood, yet carbon cost recovery is not possible as revealed by this study. As farmers operate in multitude of different complexities such as poverty, access to clean water versus need for irrigation, access to energy versus household cooking needs, health amidst climate change and many others, results have not found any studies nor projects that incorporate these problems. This means that intermediary organizations and development partners could highly play a pivotal role in connecting farmers to these schemes. However, given the high levels of farmer peer connection, and networking, cooperative structures are best fit for the implementation and monitoring phases (figure 26). The categorization of the requirement phases in this study are as a result of own systematic literature, interview findings breakdown and best practice of pilots and other carbon projects in the developing country context. The most outstanding requirement is the pre-project development phase. This phase plays an important role in fact finding and needs assessment. It is a phase that unravels potential beneficiary perceptions and attitudes towards the success of the following phases in terms of behavioural change.

Figure 26: Illustration of CCS entry requirements for cooperatives



Source: Author's compilation

5.2.4 Risks

The same categorization of the entry requirements was also used to align phase risks as revealed from both literature and findings of this study. The most pertinent risks highlighted in this study are during the pre-project development phase such as behavioural and financial risks. These pose significant threats once not mitigated and managed well because small holder quick money requirements ultimately influence their farming behaviour. Although, no study has revealed how possibly these risks can be mitigated fully hence gaps for a more informed research-oriented approach since these are common risks which have been suggested and mitigated in all phases of different carbon credits projects elsewhere. With the rising climate change effect on small holder farmer households in developing countries, it is a great risk no to do something. CFP promotion is lesser regret option than doing nothing in the debate of whether CCS actually contribute to actual emission reductions.

As established by this study, current CFP application by respondents in cooperatives shows Business as Usual (BAU) scenarios which does not yield carbon credits under different standards. For Agriterra and the community of practice ecological assessments for destructive farming practices is needed Opportunities in the studied cooperatives in form of growing number of youth membership, dominating women memberships, stakeholder support, international fair trade certification and dominating control within their value chains as revealed by this study can be a means of harnessing and CCS participation through charismatic carbon interventions.

CHAPTER SIX:

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Carbon Farming Practices

This study has discovered that compost is the most applied OFP (54%) while manure and compost combination is largely applied as well (32%) of the respondents amongst cooperatives. They are suitable amendment for enhanced carbon sequestration, soil fertility improvement and water retention but with significant yield and GHG emissions trade-offs. Safeguards have been explored to ensure quality and minimise such trade-offs such as proper mixtures and management. Dilemmas about rightful quantities, consistent supplies competing uses of residues for biochar and technologies required clarity before implementation.

In addition, this study has revealed that most cooperatives (32%) apply a combination of all CoFPs in this study. With crop rotation as the most applied CoFP, attention to specific crops to be used is of great significance due to the nitrogen and nutrient fixation and depletion roles amongst inappropriate crops. More so, the study has confirmed that 50% of the cooperatives apply the intercropping CFP among IFPs in this study. Integration of crops, livestock and trees on the same piece of land is not common among cooperatives.

Irrigation, nutrients, pest, disease and weed management during CFP implementation require proper attention before implementation across various farming systems because these are the ultimate determinants of sustainable farming systems. This study suggests that increased ecological benefits under carbon farming requires a combination of OFPs, CoFPs and IFPs although this requires increased economic investment which is not readily available for small holder farmers in cooperatives whose core focus earn a livelihood.

Carbon Credit Schemes

This study has also discovered international, national compliance and voluntary carbon credit schemes. Verra and Gold standard are the only CFP relevant CCS. However, However, with in-country government orientation, Uganda national compliance schemes and strategies present opportunities to adopt CFPs to achieve their NAMAs and NDC emission reduction targets through Uganda Green Growth Strategy 2017/18 – 2030/31.

There are no CFP comprehensive applicable methodologies. Specific CFP interventions ought to adopt either use current or blended methodologies with Verra or the Gold Standard or develop new customised methodologies. Whereas entry requirements for cooperatives mainly rely on technical and financial capabilities, pre-project development is the most important phase with necessities to prepare potential beneficiary perceptions and attitudes amongst cooperative for a more long term ecological behavioural change. Accomplishing this shall also have mitigated and managed the most important risk.

Overall, the promotion of carbon farming in cooperatives across smallholder farming system settings, with behavioural awareness, ground tangible outcomes through pilots, stakeholder and policy support and financial incentive are key in this effort.

6.2 RECOMMENDATIONS

Based on the findings in this study, it is recommended that carbon farming promotion and scale up is a no regret option for Agriterra interventions to scale up amongst its client cooperatives whether in arable or perennial value chains in developing countries. Agriterra should follow the following sequence of steps to support carbon farming among cooperatives.

Baselines for specific agroecological and carbon stocks assessment to establish business as usual ex ante data about CFP implementation by individual farmers as regards current sources, supply quantities, management and application of compost, manure and biochar organic farming practices. This should be done to also establish nature of crops under intercropping, cover-cropping and rotational cropping for beneficial crop residue management and minimised tillage in cases of conservation farming promotion. The assessment should also assess the frequency of livestock and trees on farmland and land share per entity for integrated farming promotion. An in-depth assessment of access to water, nutrient, pest, disease and weed management should also be part for a clear insight of the entire farming system among farmers in cooperatives.

Pilots should be established upon baseline studies to promote selected CFP combinations in prospected cooperative districts of implementation. These could have a small number of farmers to initiate while ensuring proper farm records and CFP implementation monitoring is done periodically. During this stage, cooperative extension and leadership should be groomed to re-orient their strategies while spreading awareness for behavioural change amongst farmer members. Use of this study, other studies and CFPs training manuals is paramount.

Linking cooperatives to carbon credit schemes at this level is substantiated upon successful accomplishment of the previous steps. Farmers in cooperatives should participate largely for on farm economic and ecological benefits. As such carbon credit revenues whether generated or not should supplement already existing own farmer and cooperative initiatives without external intervention.

Partnerships with the community of practice in similar interventions locally and globally is key. These may include CO_2 balance (for access to clean water), Fair climate fund (for access to clean and affordable energy), Climate Neutral Group (carbon neutral consortia), Winrock International (ecosystem services) among others. Government and local Non-Government Organizations as well as private agribusinesses involved in specific cooperative value chains are necessary. Agriterra may also align itself with carbon offsetting organizations such as International Emission Trading which is a hub of carbon offsettors and other national carbon coalitions while maintaining its cooperative and agricultural niche in production of agricultural carbon credits.

Financial instruments to build upon the previous steps should be sought from transnational corporations with or without emission reduction targets involved in value chains from Uganda present better through in setting. On the other hand in-country national corporate social responsibility programs could be re-oriented under the influence of Agriterra while also providing opportunities for offsetting corporate programs International financing platforms such as the Dutch Agri3 fund and Microsoft innovation climate fund are some of the funds that Agriterra can lobby to implement carbon farming interventions in this study and link cooperatives to carbon credit schemes.

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APPENDICES:

Annex 1: Overview of CFP dimensions and aspects from different literature sources

Authors	Dimensions	Aspects
Smith et al. (2008)	Agronomy	Improved crop varieties, crop rotations, nutrients, cover crops, less intensive cropping systems
	Nutrient management	Precise fertilisation application, No Tillage/residue management,
	Water management	Effective irrigation,
	Agroforestry	Planting trees, afforestation or reforestation
	Land cover (use) change,	Converting drained croplands back to Wetlands, croplands to grazelands
	Management of organic soils	No Tillage, avoiding the drainage
	Restoration of degraded lands	Nutrient amendments, applying organic substrates, such as manures, biosolids and composts; reducing tillage and retaining crop residues, conserving water
Shames et.al., (2012)	Agroforestry	Planting interplanting and boundary plantings of trees, woodlots, fruit orchards, reforestation, shade trees,
	Farmer Management Natural Regeneration (FMNR)	Afforestation, reforestation
	SALM	Minimum tillage, crop residues on fields, livestock enclosures, composting, agroforestry
Altieri & Nicholls (2013)	Diversification practices	Mixed or intercropping, agroforestry, intensive silvopastoral system, crop rotation, local variety mixtures
	Soil management practices	Cover crops, green manures, mulching, compost application, conservation agriculture (organic, no till)
Smith et al. (2014)	Forestry practices	Reducing deforestation, afforestation/reforestation, forest management and restoration
	Land based agriculture, (crops)	Improved crop varieties, crop rotation, use of cover crops, perennial cropping systems, agricultural biotechnology, fertilizer input, water availability, biochar application, replanting to native grasses and trees, animal manures,
	Integrated systems	Integrated livestock agriculture, mixed crop-livestock systems,
Shames et.al., (2012)	Soil nutrient management practices,	Mulching, composting, efficient fertilizer use,
	Improved agronomic practices,	Fruit orchards, crop rotation, intercropping, cover crops, tree planting, etc.
	Improved livestock management practices,	Reduced open grazing, forage development, feed improvement, breed improvement
	Restoration of degraded lands	Reforestation, diversity
Shames et.al., (2012) & Chidawanyika & Tirado (2015)	Soil conservation measures	Water catchments, water conservation
	Water conservation measures	

FAO (2016)	Conservation Agriculture	Reduced tillage, residue management (mulching, intercropping), crop rotation
	Integrated soil fertility management	Compost & manure management, efficient fertilization application, use of effective micro-organisms
	Irrigation	Year-round cropping, efficient water utilization,
	Agroforestry	Tree based conservation agriculture, FMNR,
	Crop diversification	New crops and varieties, pest management
	Improved livestock and feeding practices	Reduced open grazing, forage development, feed improvement, breed improvement
Rosa-Schleich, et al. (2019)	Single measures	Cover crops, green manure, crop rotation, reduced tillage, intercropping, agroforestry, structural elements,
	Combined practices	Conservation agriculture, mixed farming, organic agriculture

Annex 2 Sample Carbon Project Development Cost Break down

Total costs for all activity modules over 10 years are €341,293.

Activity Modules	**Unit**	**Price (EUR)**
Service phase 1: Project development and validation		
1. Carbon scoping study	Per project	4,800
2. Carbon feasibility study (eligibility assessment, carbon ex-ante estimate)	Per project	14,700
3. PDD Development Study incl. (GIS, SOP)	Per project	28,000
4. Management Information System (Excluding hosting data on cloud. Software will be provided at no licence fee based on EULA.	Per project	29,400
5. Project Validation	Per project	16,800
Sub-total Service phase 1	Per project	**93,700**
Service phase 2: Project monitoring and maintenance (10 years)		
6. Monitoring and Verification (3 x verification)	Per project	51,100
7. Project training & MIS system	Per project	74,200
8. Innovation watch	Per year €1,600	16,000
9. Reporting & communication (incl. 3 physical meetings of one person per year)	Per year €3,200	32,000
Sub-total Service phase 2 for 10 years	Per project	**173,300**
Expenses (Travel €54,293, MIS software maintenance €20,000) Travel Cost - The costs include a budget for 10 missions (international flights) to the project area MIS Software maintenance - The budget includes regular software and security updates of the MIS and monitoring Apps developed	Per project	74,293
Total costs incl. expenses		**341,293**

Annex 3 Online Survey template

Carbon Farming Opportunities for Crop Cooperatives in East Africa. Online Survey 2020
Filling this questionnaire shall help Agriterra a Dutch International NGO to identify what carbon farming practices are practised by farmers and their benefits in order to integrate them to carbon credit schemes as a way of incentivizing actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. This survey takes 25-35 minutes to fill (For support WhatsApp, +31 616 036 358)

Section 1

About the Cooperative or Rural Producer Organization or Farmer Group
(A brief overview about the cooperative)

1.Name of Cooperative or Rural Producer Organization or Farmer Group

2.Position in Cooperative or Rural Producer Organization or Farmer Group

3.District of Cooperative or Rural Producer Organization or Farmer Group

4.Number of registered members of Cooperative or Rural Producer Organization or Farmer Group

5.Number of Female members of Cooperative or Rural Producer Organization or Farmer Group

6.Number of Male members of Cooperative or Rural Producer Organization or Farmer Group

7.Number of youth (18 -35 years) members of Cooperative or Rural Producer Organization or Farmer Group

8.What is the major crop grown by the Cooperative or Rural Producer Organization or Farmer Group?

9.What other crops are grown by the Cooperative or Rural Producer Organization or Farmer Group?

10.Region of the Cooperative or Rural Producer Organization or Farmer Group? (Tick ONLY one region)
Write your answer

11.What is the Annual sales revenue/turnover of the Cooperative or Rural Producer Organization or Farmer Group? (Tick ONLY one range)
Write your answer

12.Where do you sell your main crop? (Tick all applicable markets)

☐ Local & Domestic Markets (Within Uganda)

☐ East African Regional Markets (Kenya, South Sudan, Tanzania, Rwanda, Burundi)

☐ Other African Markets

☐ Global Markets

13.Is the cooperative certified under any local, regional or international standards/certifications? (Like UNBS, NOGAMU, Fairtrade, Rainforest Alliance...)
Write your answer

14.If yes, please specify the certifications you have;

15.What are the functions of cooperative in the main value chain? (Tick all applicable functions)

☐ Input (Provision of seeds, fertilisers, land, labor, etc)

☐ Production (Growing of crops)

☐ Collection and Trade of farmers' produce

☐ Processing (Value addition)

☐ Wholesale and or Export

☐ Retail

☐

Section 2

About Farming Practices

In this section, your responses are given on behalf of the farmers of the cooperative.

16.Have you heard of the term Carbon Farming Practices?
(Organic farming / Conservation farming / Integrated farming)
Write your answer

17.How do farmers increase soil fertility? (Tick applicable option only)
Write your answer

18.Which of the following farming practices do members practice? (Tick all applicable practices)

☐ Compost Application (decayed organic material used as a fertilizer)

☐ Manure Application (animal dung used for fertilizing)

☐ Biochar Application (charcoal produced from plant matter and stored in the soil)

☐ Vermiculture (cultivation of earthworms, especially in order to use them to convert organic waste into fertilizer)

☐ None of the above

☐

19.What do farmers gain by using the some of the farming practices in the previous question?

(In terms of yield, revenues, profits, costs, soil fertility, flowering, water holding capacity, natural organisms, pest, weed and disease control)

20.What are the challenges farmers face in using the above organic farming practices?

21.Is there any degraded land or land abandoned by farmers in the cooperative?

- Yes
- No

22.Which of the following farming practices do farmers practice? (Tick all applicable)

- Zero or Reduced Tillage (No / minimun tractor use during preparation of land for growing crops)
- Mulching (cover the soil between plants with a layer of material)
- Cover crops
- Crop rotations
- Residue use
- None

23.What do farmers gain from using the farming practices in the previous question?
(In terms of yield, revenues, profits, costs, soil fertility, flowering, water holding capacity, natural organisms, pest, weed and disease control)

24.What are the challenges farmers face in using the above farming practices in the previous question?

25.Which of the following farming systems is practiced by farmers ? (Tick ONLY one applicable)
Write your answer

26.If mixed, what farming combinations are practiced amongst farmers?
Write your answer

27.What do farmers gain from using the farming systems in the previous question?
(In terms of yield, revenues, profits, costs, soil fertility, flowering, water holding capacity, natural organisms, pest, weed and disease control)

28.What are the challenges farmers face in using the above farming systems in the previous question?

29.How do farmers manage pests and diseases?

- Biological control (use of useful living organisms, such as predators or parasites)
- Cultural control (changing the environment to make it undesirable for pests and diseases)
- Chemical control (using pesticides, fungicides and bactericides)
- Uses of a combination of cultural, biological and chemical methods
- None of the above

30.What do farmers gain from using the control method chosen in the previous question?
(In terms of yield, revenues, profits, costs, soil fertility, flowering, water holding capacity, natural organisms, pest, weed and disease control)

31.What are the challenges farmers face in using control method chosen in the previous question?

32.How do farmers water their crops?

- Only Rainfall
- Only Irrigation
- Both Rainfall and Irrigation

33.What do farmers gain from using the method chosen above?
(In terms of yield, revenues, profits, costs, soil fertility, flowering, water holding capacity, natural organisms, pest, weed and disease control)

34.What are the challenges farmers face in using method chosen above?

35.How do farmers control weeds?

- Hand weeding

- ○ Herbicides (Spraying)
- ○ Mechanical weeding
- ○ Mulching (cover top soil with material)
- ○ ♣ Other

36.What do farmers gain from using the method chosen above?
(In terms of yield, revenues, profits, costs, soil fertility, flowering, water holding capacity, natural organisms, pest, weed and disease control)

37.What are the challenges farmers face in using method chosen above?

38.Have you heard of the term Carbon Credits or Carbon Markets?
(Markets where farmers are paid for adopting organic, conservation and integrated farming)

- ○ Yes
- ◉ No
- ○ Maybe

39.If yes, has the cooperative made efforts to join or participate in Carbon Credits or Carbon Markets?
Write your answer

Section 3

Carbon Farming Support to farmers

40.Has the cooperative received any kind support towards adoption of organic, conservaton and integrated farming practices?
(In terms of extension, training, access to finance, access to markets etc)
Write your answer

41.If yes, where does the support come from?
Write your answer

42.Would your cooperative or farmer group be interested in joining carbon markets to be paid for adopting carbon farming?
Write your answer

43.Please give reasons for your response above?