GENDER PREFERENCES, SOIL AND WATER CONSERVATION AND HOUSEHOLD INCOME: CASE OF SMALLHOLDER FARMERS IN NORTHERN RWANDA

ILDEPHONSE MUSAFILI

A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Doctor of Philosophy Degree in Agricultural Economics of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original research work and has not been presented in this university or any other for the award of a degree.

Signature 6th Semptember 2023

Ildephonse Musafili **Date**

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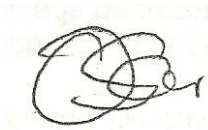
Recommendation

This thesis has been submitted with our approval as University supervisors.



Signature 7th September 2023

2023

Dr. Oscar Ingasia Ayuya, PhD **Date**

Department of Agricultural Economics and Agribusiness Management

EGERTON UNIVERSITY

Signature 7th September 2023

Dr. Eliud Abucheli Birachi, PhD **Date**

International Centre for Tropical Agriculture

CIAT-RWAND

DEDICATION

This thesis is dedicated to my beloved wife, Jeannette, our children Narjesse, Gaëlle, Karla and Xander), and my parents and sisters.

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ABSTRACT

Under the National strategy for transformation, Rwanda has aimed to modernise and increase agricultural productivity, and promote sustainable management of natural resources towards a green economy, while mainstreaming gender across strategies and investments to achieve gender equality and ensure equal opportunities for men and women. This has resulted in increase of female share in agriculture production and natural resources management as laborers and decision-makers. Despite the country's performance in gender development index (0.941), the worry is if rural women farmers have adequate opportunities to participate in production and decision-making processes as men do; and particularly, what would be the factors influencing alternative investment in soil and water conservation (SWC). Furthermore, the nature, trends and patterns of this feminisation of agriculture and the impact of women's empowerment on SWC are still uncertain. This could be attributed to the lack of data on gender preferences for multiple SWC attributes, and the absence of reliable information on their trade-offs, as well as unreliable evidence on the effect of SWC investments on household income. To fill this gap, this study seeks to contribute to sustainable natural resources management and household welfare through assessing gender preferences in SWC in Northern Rwanda. This study used a mixed-method approach involving focus group discussions, key informants and participatory mapping; and surveys to collect data from a sample of 653 respondents including 253 males and 400 females. Data were analyses using thematic content analysis, GIS mapping, count scores and pearson correlation, and econometric models such as multinomial logit, iterative seemingly unrelated regression equations and instrumental variable quantile regression. Results on land uses show that overtime change in cropland (increased to 48% and then 34%) has led farmers to explore new off-farm opportunities. Most adopted SWC practices at homestead were organic manure (85%), ridge farming (65%) and NPK (52%). Results show preferences heterogeneity in SWC, and significant trade-offs and gender differences in preferences for SWC scenarios. Furthermore, results show that women's empowerment has mixed effects on SWC strategies. Lastly, financing investment in SWC significantly increases income five times for middle-income earners compared to the poor. Policy makers should design appropriate farm conservation and livelihood strategies to help the poor finance investment in SWC. For example, introducing village financial and social protection schemes in SWC, and labor saving technologies can enhance empowerment through increase women's shares and decisions. Given the cross section nature of our data, further studies should focus on longitudinal or panel data for simulation analysis of SWC.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAECS	Access to Agricultural Extension and Communication Services
AED	Anti-Erosion Ditches
AfDB	African Development Bank
AGRA	Alliance for a Green Revolution in Africa
AGS	Agriculture Gender Strategy
BWS	Best Worst Scaling (BWS)
CE	Choice Experiment
CF	Control Functional
CIAT	International Center for Tropical Agriculture
CIP	Crop Intensification Program
COM	Compost and Organic Manure
DAP	Di-Ammonium Phosphate
DRC	Democratic Republic of Congo
EAC	East African Community
EDPRS I	Economic Development and Poverty Reduction Strategy I
EDPRS II	Economic Development and Poverty Reduction Strategy II
FAO	Food and Agriculture Organization
FATE	Feminisation Agricultural Transition and Rural Employment
FGD	Focus Group Discussion
GDI	Gender Development Index
GDP	Gross Domestic Product
GoR	Government of Rwanda
Ha	Hectares
HAI	Household Domestic Assets Index
HUF	Household Utility Function
ILO	International Labor Organisation
IVQR	Instrumental Variable Quantile Regression
Kg	Kilogram
KIIs	Key Informants' Interviews
LTR	Land Tenure Regularisation
LUCP	Land Use Consolidation Program

LWH	Land Husbandry, Water Harvesting and Hillside Irrigation
MDG	Millennium Development Goal
MIGEPROF	Ministry of Gender and Family Promotion
MINAGRI	Ministry of Agriculture and Animal Resources
MNL	Multinomial Logit
MT	Metric Tons
NGO	Non-Governmental Organizations
NHE	New Household Economics
NISR	National Institute of Statistics of Rwanda
NMG	Nutrition, Market and Gender
NPK	Nitrogen, Phosphorus and Potassium
NST-1	National strategy for transformation for Rwanda
NTAE	Non-Traditional Agricultural Export
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
OMEP	Orthogonal Main-Effect Design Plan
pH	Potential of Hydrogen
PRA	Participatory Rural Appraisal
PSTA	Strategic Plan for Agriculture Transformation
RUT	Random Utility Theory
RWF	Rwandan Francs
SGDs	Sustainable Development Goals
SSA	Sub-Saharan Africa
ISURE	Iterative Seemingly Unrelated Regression Equations
SWC	Soil and Water Conservation
TLU	Tropical Livestock Unit
UNDP	United Nations Development Programme
US$	United States Dollar
WEAI	Women Empowerment in Agriculture Index
WUAs	Water Users Associations

CHAPTER ONE
INTRODUCTION

1.1.Background Information

In sub-Saharan Africa (SSA), agriculture serves as the basis for economic growth, food security, poverty reduction, and employment provision for rural men and women families. About 64% of the rural population and slightly over 60% of the workforce is engaged in agricultural production. The sector contributes about 20% and 32% to the total merchandise exports and the national gross domestic product (GDP) respectively (Alliance for a Green Revolution in Africa [AGRA, 2018]). The share of female labor force in agricultural production is about 75%. Women contribute to about 42% of family farm labor, compared to 20% by men (Matthew *et al.*, 2022). More than 76% of women in the working population are in vulnerable employment, while 56% live in extreme poverty, at less than US$1.25 per day (International Labor Organisation [ILO, 2018]).

Women are increasingly taking up the management of smallholder farms in many SSA countries like Rwanda, however, their participation in agricultural transformation activities has been debatable (Kawarazuka *et al.*, 2022; Najjar *et al.*, 2022). This transformation requires productivity growth, which depends on women's increased uptake of improved technologies and greater use of agricultural inputs that improve the productivity of labor and land (Ecker, 2018; Gosnell, 2021). The rising agricultural productivity leads to the supply of surplus production to markets, which creates job opportunities in the off-farm economy and increases rural incomes. The latter generates market demand for more diverse products leading to more processing and other non-farm activities such as packaging, transporting and trading (Aragie *et al*., 2022; Diao *et al.*, 2023). However, the process of agricultural transformation is still constrained by women's access to productive resources such as inputs, technologies, extension services, and mainly hired labor.

Despite the increasing female share as laborers and decision makers in agricultural transformation, termed as "agricultural feminisation" (Haug *et al*., 2021; Kawarazuka *et al.*, 2022), the nature and trends of the feminisation of agriculture is not well known, as well as its impact on women's empowerment and soil and water conservation (SWC) is still uncertain. The debate on this issue focuses on two fundamental questions – (i) Do women have adequate opportunities to participate in the agricultural production, processing and management of resources, and welfare benefits as men do; and, (ii) what would be the factors influencing alternative outcomes concerning women's decision-making regarding agricultural operations, investment and natural resources conservation. Evidence indicates that women

play distinctive roles in productive, generative and communal management actions, however, their access to both financial and productive resources constitute a challenge because they have little voice in regards to production, commercialisation and management of the environment (Phiri *et al*., 2023).

Feminisation of agriculture involves changing farm roles and managerial decision in production, processing and management of natural resources as a result of shifting gender power relations at household scale. Increased women' role and decision-making have positive effects on agricultural transformation in terms of diversifying agricultural production and increasing the share of agricultural export products (Imai, 2019; Laborde *et al.*, 2019). In Rwanda, gendered work and decision-making were linked to both agricultural feminisation and transformation of agriculture through nutrition-sensitive production system, value chain development, non-farm rural entreprise development and climate-resilience (Aragie *et al*., 2022; Diao *et al*., 2023). A study by Phiri *et al*. (2022) indicated that factors related to gender work patterns and women's differentiated roles, knowledge, perception, preferences and decision-making explain the process of agricultural feminisation.

Over the last two decades, Rwanda has undergone one of the most rapid structural and agricultural transformations in low-income agrarian nations in history. Through vision 2020 and the second economic development and poverty reduction strategy (EDPRS II), Rwanda sustained a 8% growth in gross domestic product (GDP), resulting in a 30% reduction in poverty and increased representation of women in public services (Ayittey, 2017; World Bank, 2020). Despite the fact that the country ranks well in the gender development index (GDI) with a value of 0.941 (UNDP, 2018), gender remains one of the most pervasive categories of social inequality (Fischer, 2015; Zaborskis & Grincaite, 2018). Gender disparities in rural areas are still prevalent (GoR, 2018). For instance, women engaged in farming activities have longer working hours than men. More women are involved in primary agriculture than in value addition and transportation of food (AfDB, 2015).

The current national strategy for transformation (NST1)-2018-2024 aims to modernise and increase agricultural productivity, while promoting sustainable management of the environment and natural resources towards a green economy. NST1 recommends that all investments, policies, sector strategies and plans should consider social inclusion, gender equality and ensure equal opportunities for men and women, and environment and climate change as crosscutting issues. However, while such policies have focused on improving productivity and profitability on farms managed by men and women, they were assumed to be gender-neutral as they considered a household like a unified decision-making entity.

Studies on internal household dynamics point out that they fail to accommodate gender preferences and decision-making can lead to inequality and have welfare consequences (González & Meriggi, 2016; Gulati *et al.*, 2016).

As stated by the strategic plan for the environment and natural resources (2018-2024) sector, about 96% of rural households in Rwanda rely directly on agriculture for their livelihood, and operate on fragmented plots of average sizes of 0.24 ha using multiple SWC strategies. The SWC strategies comprise a package of practices and attributes that could improve the sustainability of smallholder farm productivity and profitability (Brown *et al.*, 2022). Further, a SWC strategy combines complementary or substitutes practices aimed at environmental management and resilience to climate change through integrated and sustainable water resources (IWRM), land resources (LRM), and forest and agroforestry resources management (Ochieng *et al*., 2021; Shrestha *et al.*, 2021). Farmers make trade-offs and equity when choosing SWC practices that are nutrients saving (terracing, contour bunds, trenches, and waterways), moisture saving (fallows, intercropping, mulching, and tree planting, etc.), as well as nutrient adding (mineral fertilisers and organic manure) (Bizoza & De Graaff, 2012; Debie, 2021; Haggar & Rodenburg, 2021). Moreover, SWC strategies serve as mitigation responses to reduce soil degradation mainly on steep slopes, and thus improve the productivity of the farm (Du *et al*., 2021). Studies show that the intensity of use of SWC strategies is influenced by extension services, external inputs, the productive capacity of the land and household wealth status (Kim *et al.*, 2022; Ndeke *et al.*, 2021; Oyetunde-Usman *et al.*, 2021).

This study was based on the application of gender analysis frameworks using the agricultural household model (AHM). The study makes numerous contributions in agricultural economics and natural resources management. It first explores the farmers' perception of agricultural feminisation, preferences and impact of SWC on women's empowerment and household welfare. Second, it examines the nature, trends and patterns of feminisation of agriculture and natural resources management and its impact on SWC decision-making. Emphasis is placed on gender differentiated roles and decision-making, knowledge, perception, and adoption of SWC technologies. Third, it assesses gender preferences for multiple SWC attributes using the best-worst scaling (BWS) experimental design as one of the first application in agricultural economics in SSA and particularly in Rwanda. Fourth, the study contributes to the literature that uses women's empowerment in agricultural index (WEAI) by examining its effects on SWC strategies. Lastly, it explores the impact of investing in SWC on household income.

1.2. Statement of the Problem

Soil degradation, loss of soil fertility, and reduction in water for farming constitute a hindrance to farm productivity and agricultural transformation in developing countries. This fundamental problem is pervasive in the volcano farming region of Northern Rwanda, where high poverty levels and adoption of unsustainable intensification technologies are among the leading causes of losses of farm productivity and the high gender productivity gap. This scenario will intensify if no proper interventions in SWC are made at farm level. Despite the country's performance in GDI, and an increase in the female influence in agriculture as laborers and decision makers, the gap in productivity persists. Thus, it is unclear if rural women farmers have adequate opportunities to participate in decision-making processes as men do, and the factors that would influence alternative investment in SWC. Furthermore, the nature, trends, and patterns of agricultural feminisation is not well understood and its impact on women's empowerment and SWC is still uncertain. This is the dearth in knowledge that this study seeks to fill.

1.3.Objectives

1.3.1. General Objective

The main objective of this study is to contribute to sustainable natural resources management and household welfare through enhanced effectiveness of gender preferences and SWC in Northern Rwanda.

1.3.2. Specific Objectives

i. To analyse the perceptions of local communities on gendered work patterns, adoption, and SWC decision-making.
ii. To assess gender preferences for multiple SWC attributes.
iii. To determine the effect of women's empowerment on labor time allocated to SWC strategies.
iv. To assess the impact of SWC investment on household income.

1.4.Research Questions

i. What are communities' perceptions on gendered work patterns, adoption, and SWC decision making?
ii. What are the gender preferences for multiple SWC attributes?
v. What are the effects of women's empowerment on labor time allocated to SWC strategies?
iii. What is the impact of SWC investment on household income?

1.5. Justification of the Study

SWC practices have a significant impact on environmental management and resilience to climate change, household welfare, and food and nutritional security. These practices serve as a pathway to sustainable agricultural intensification to achieve food security and reduce environmental impacts of agriculture by focusing on narrowing yield gap on existing agricultural land while improving resource use efficiency. Therefore, the findings of the study will benefit stakeholders in the sector, particularly small scale farmers and women by informing policies that address rural poverty issues, reduce inequality and spur economic growth while tackling climate change among farmers. This is in line with the Sustainable Development Goals (SGDs), primarily "*Ending poverty and other deprivation (goal one); end hunger, achieve food security and improved nutrition and sustainable agriculture (goal two); and achieve gender equality and empower all women and girls (goal 5).*"

Generally, the study contributes to the gender and development debate in agricultural economics and natural resources use and management. The research findings provide insights for policy makers regarding pro-poor and gender-oriented development programs and implementation in Rwanda. This in in line with the millennium declaration to promote gender equality, eliminate all forms of gender-based discrimination, and attain the empowerment of women as a pathway for combating poverty, hunger, and disease to stimulating sustainable development.

This study will also equip small-scale farmers especially women farmers with better understanding of diverse SWC strategies, attributes and scenarios that will improve and facilitate the adoption of more diversified production systems that transform farming systems. Specifically, farmers will be exposed to gender approaches for scaling-up and promoting packages of SWC.

Furthermore, this study complements and adds to the existing literature on gender and development (GAD) which addresses some of the policy gaps and inequalities in women's and men's roles and decision-making in SWC. Lastly, the main contribution of the study to academic knowledge is on methodology with application of different econometrics models to assess preferences and SWC impacts. These include: Iterative Seemingly Unrelated Regression Equations (ISURE) and instrumental variable quantile regression (IVQR) to assess SWC impacts, and the novel application of best-worst scaling (BWS) experiment and multinomial logit (MNL) model with maximum difference to assess gender preferences for SWC.

1.6.Scope and Limitation of the Study

As indicated, this study builds on gender analysis frameworks and explores the impact of agricultural feminisation on SWC and household welfare. Specifically, the study focused on Burera, Gakenke, and Musanze districts of Northern Rwanda due to farming intensity, high productivity, and comparative advantage in non-traditional agricultural export crops (NTAEs). The NTAEs crops which include Irish potatoes, beans, maize, coffee, and cassava have a significant contribution to rural employment as they are major export crops for the transborder trade to Uganda, Burundi and the Democratic Republic of Congo (DRC). Tourism is one of the significant off-farm activities common in the study area. In addition, the districts constitute a hub for agribusiness development due to the proximity to Uganda and DRC borders in Musanze town.

The unit of measurement was farm households producing one of the mentioned NTAEs crops. There were three types of farm households: a household with both male and female decision-makers, a household with a single male decision-maker, and a household with a single female decision-maker. Thus, the unit of analysis was two decision-makers (who principally are spouses) within a household. A respondent was any household member (male and/or female) aged at least 18 years old, who actively participate in agricultural investment, and is knowledgeable about farming practices, household incomes, as well as considered as one of the decision-makers in the household. Data collected was cross-section in nature covering two agricultural seasons that is season 2019A and Season 2019B. Agricultural season 2019A started from September 2018 to mid-February 2019, while season 2019B was from February 2019 to June 2019.

1.7.Definition of Terms

Agricultural transformation: the process by which an agri-food system transforms over time from being subsistence-oriented and farm-centered into a more commercialized, productive, and off-farm-centered (Jayne *et al.*, 2019). The process leads to higher productivity, increased investment and commercially oriented farming to increase household incomes, and strengthen the links between farming and other sectors of the economy.

SWC strategy: encompasses combined and interrelated approaches of soil conservation practices, soil fertility management practices, and integrated soil management and water conservation technologies, as production, conservation and livelihood attributes.

SWC investments: refers to farm plot level time and finance (as measured by total economic benefits or opportunity costs of time) invested in the farmers' plots using single, multiple, complementary or interrelated SWC practices.

Non-traditional agricultural export (NTAEs) crops: this are high value crops (HVC) produced for commercial purpose. such as Irish potatoes, beans, maize, and cassava, and have significant contribution to rural employment.

Feminization, agricultural transformation and rural development (FATE): is a collaborative research project within an international research partnership between the University of Bern, Switzerland, and the International Center for Tropical Agriculture (CIAT), Rwanda. The project examines if and under what conditions rural employment in the NTAEs leads to both increased asset building and individual well-being of women and men in rural households.

Financing SWC investment: consists of paying hired labor for overall SWC investment activities because household members work outside the farm. It exhibits high economic benefits-that links farm investment with non-farm income.

Gender preferences: the economic value males and females attach to farm investment strategies based on their social norms and values, division of labor, access to and control over productive resources, and decision-making power between household decision-makers and how they produce and consume by stating their best and worst attributes.

Integrated soil management and water conservation (SM and WC) is a set of sustainable land management practices involving the combined use of physical structures including fertilizers, organic inputs, and improved germplasm based on farmers' knowledge of local conditions (Vanlauwe *et al*., 2010).

Soil conservation (SC) practices: refer to agronomic or management practices (ranging from biological to physical structures) used in the farm to reduce soil erosion, increase crop yield, and make returns to farm investment (Aryal *et al*., 2018). They include traditional methods (fallow, grazing, contour ploughing, and leaving crop residues) and current methods (ridge farming, progressive terraces, bench terraces, anti-erosion ditches, hedgerows within the farm or with trenches, and agroforestry).

Soil fertility management (SFM) practices: implies the optimisation of resources for crop production while minimising adverse environmental effects (Young *et al*., 2021). If adopted, these farming practices (e.g., NPK, Urea, DAP, organic manure, pesticides and lime) can improve the soil's quality and fertility, increase mineral efficiency and crop productivity.

Women's empowerment in agriculture: refers to the economic empowerment of males and females as measured by adequacy in each of the five domains and ten indicators of the WEAI (Alkire *et al.,* 2013).

Household income: aggregating all receipts (monetary or in kind) by individual household members during a period of 12 months received from different sources: agriculture farming (income from crop farming), livestock raising (income from selling livestock and livestock products), off-farm opportunities, renting houses and assets, remittances, and interests and dividends.

1.8.Thesis Structure

This thesis has seven chapters, and is organized into four distinct papers. The background chapter focuses on research issues and the rationale for the study. Chapter two provides a literature review related to the study. In chapter three, the paper discusses about agricultural feminization: trends in gender work patterns, perceptions and adoption of SWC practices using a mixed method approach. Chapter four talks about gender preferences for multiple SWC attributes using a BWS experiment. Chapter five is concerned with the effect of women empowerment on labor time allocated to multiple SWC strategies. Chapter six provides a detailed discussion about the impact of SWC investment on household income using an instrumental variable quantile approach. Finally, chapter seven discusses policy implications and suggests further research directions in light of the findings in this study.

CHAPTER TWO
LITERATURE REVIEW

This chapter provides a contextual review of gender and SWC, including women's empowerment, gender preferences, household income, and farm investment. It also provides theoretical and conceptual frameworks to measure variables and indicators.

2.1. African Agriculture and Agricultural Feminisation

Women constitute the most significant share of the labor force in agriculture. Globally, the share is more than 40%, and 75% in SSA countries (Matthew *et al.*, 2022). Gender labor patterns in rural areas have been changing in response to agricultural transformation factors that disproportionately pull men out of agriculture. Women's role in agriculture is therefore increasing, a phenomenon described as feminisation of agriculture (Kawarazuka *et al.*, 2022). In addition to the structural transformation factors, feminization of agriculture has been associated with the growing number of households headed by women decision-makers and the development of labor-intensive high value crops (Patra *et al.*, 2019). Agricultural feminisation, mainly through labor and managerial roles have implication in agricultural transformation and women empowerment (Lamichhane *et al.*, 2022).

Agriculture transformation involves five critical transitions, these are urbanization, growth of the rural non-farm economy, dietary diversification, a revolution in the supply chains, and retailing and transformation of the agricultural sector (Dawe, 2015). Thus, agricultural transformation involves moving an economy from low productivity to high productivity in all sectors. As agrifood systems evolve from subsistence farming, agricultural productivity rises and farmers start supplying surplus production to markets, which creates job opportunities in the off-farm economy and increases rural incomes (Diao *et al.*, 2022). These phases of transformation are driven by short and long-term determinants presented in Figure 2.1.

Three indices are embedded in different phases of agricultural transformation. The agricultural openness index indicates the share of agricultural export in the agricultural value addition; the commercialization index defines the share of agricultural products; and the product diversification index captures the extent to which farmers diversify agricultural production (Laborde *et al.*, 2019). Both the indices and phases of transition are in line with the phases of the structural transformation in Rwanda's agrifood system outlined by Aragie *et al.* (2022), and include nutrition-sensitive food production systems, inclusive value chain development , non farm rural entreprise development , and climate-resilient sustainable of both crops and livestock.

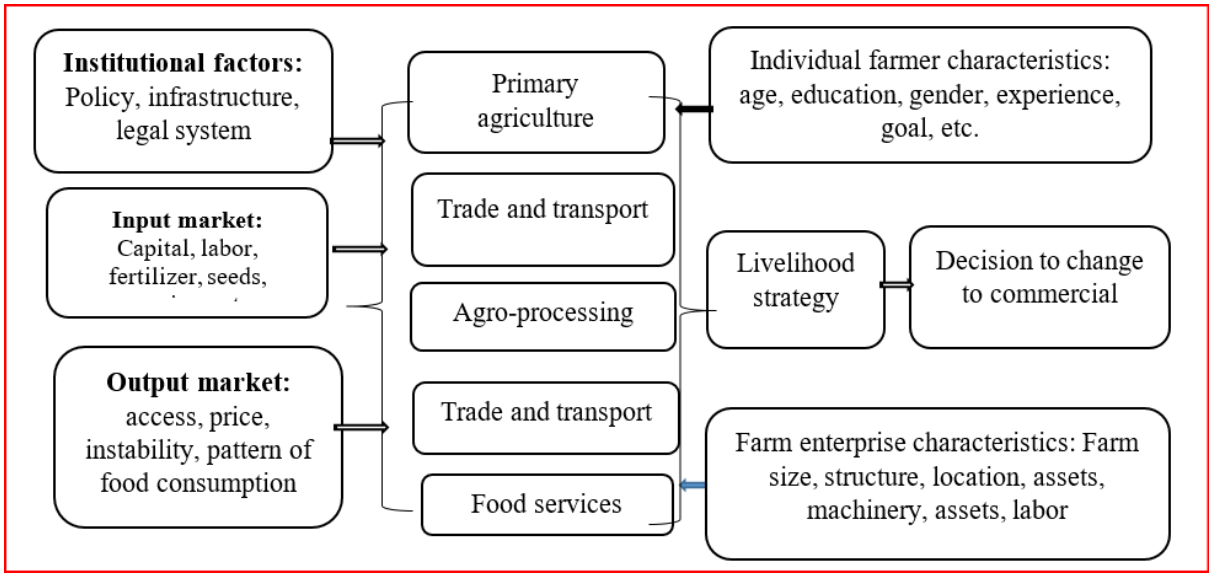

Figure 2. 1. Structure and drivers of transformation in Rwanda's agrofood-system

Source: Adapted from Diao *et al.* (2022) and Truong (2009)

Using both computable general equilibrium (CGE) and rural investment and policy analysis (RIAPA) models, Diao *et al.* (2023) indicated short term and longterm determinant have greater impact on future drivers of inclusive agricultural transformation in Rwanda such as growth of income and employment, reduction in hunger and poverty, and the improvement of diet quality.

Short-term determinants are both internal and external factors to the farm as well as institutional factors. The internal factors include land, labor availability, capital, technology, and location. Rising labor productivity leads to production beyond subsistence. Factors external to the farm are factor markets and output markets. The former constitutes inputs markets such as land accumulation and consolidation, labor market and non-farm work; capital market and access to credit, and extension services. Institutions related to legal systems, organisational structure, and infrastructure (Kabiti *et al.*, 2016; Okello *et al.*, 2012). A study by Carletto *et al.* (2017) indicated a positive correlation between the short term determinants and agricultural commercialisation in the Africa's agricultural transformation of the food system.

Another set of long-term determinants influencing agricultural transformation of the food system include rural infrastructure, and an efficient combination of inputs and outputs. Improved infrastructure, especially roads, decreases the cost of a wide range of attractive manufactured consumer goods thus enhancing the profitability of new technology (Fischer & Qaim, 2012; Okello *et al.*, 2012). Development in rural infrastructure has implications on prices, and diffusion and use of technology such as irrigation improved varieties and

fertilisers. Studies identified that poor access to infrastructure is an obstacle to agricultural feminisation due to limited access to markets and reduced levels of transformation (Minot *et al.*, 2023; Wiggins, 2018).

2.2. Measuring Women's Economic Empowerment among Household Members

Women's empowerment contributes to improved household income and local economies and to gender relations at the individual, societal and environmental levels. Table 2.1 presents five domains and ten indicators of WEAI as a measurement of women's economic empowerment at household level (Alkire *et al.*, 2013).

Table 2. 1. Domains and indicators of women's empowerment in agriculture

Domain	Indicator	Weight
Production	Decisions on production	1/10
	Autonomy in production	1/10
Productive resources	Ownership of assets	1/15
	Asset disposal and acquisition	1/15
	Access to and decisions on credit	1/15
Income	Control over use of income	1/5
Leadership	Group membership	1/10
	Speaking in public	1/10
Time allocation	Workload	1/10
	Leisure	1/10

Source: Adapted from Alkire *et al.* (2013)

The domain of agricultural production comprises two indicators of empowerment. The production domain is concerned with individual decisions with respect to their input in agricultural activities (crop farming and livestock rearing), as well as personal autonomy in making agricultural production decisions. Higher agricultural productivity was found to be achieved in households where women take production related decisions (Diiro *et al.*, 2018). Lower returns were associated with gender differences in access to various input levels (Gebre *et al.*, 2021). Further, issues linked with unbalanced decisions can lead to women's lack of fair benefits from agricultural activities (Avila-santamaria & Useche, 2016).

The domain of productive resources captures the individual's ownership of assets, asset disposal and acquisition, and access to and credit decisions. Access to economic and financial resources for agricultural production can ensure a reduction in poverty and food insecurity (Malapit *et al.*, 2019). Both males and females' ownership and transfer of

productive assets can influence women participation in human development and economic activities (Ankrah *et al*., 2020; Croppenstedt *et al.*, 2013). Ogato *et al*. (2017) argued that there are gender differences in accessing productive resources such as land, irrigation water, credit and agricultural services. Further, Ajadi *et al.* (2015) and Elias *et al.* (2014) indicated that despite significant role of women in crop and livestock production, culture contributes to gender differences in access to agricultural extension, and decision-making regarding productive resources.

Decision and control over the use of income reflect gender differences over households' income and expenditures. For example, Balayar and Mazur (2021) argued that women that manage household cash have more freedom to spend income, and have a strong sense of dignity and empowerment. Education and farm size positively contributed to household income and decision-making for women unlike age, family size and indebtedness (Roy *et al.*, 2017). The contributions of women arose from making decisions on post-harvest operations especially in drying, sorting, cleaning and storage (Saikia *et al.*, 2021).

An important aspect of women empowerment is an individual's potential for leadership within a household and influence in their community through active membership and comfort to speak in public. In Rwanda, rural women have the lowest levels of schooling and highest illiteracy rate estimated at 23.3%. Consequently, women are faced with lack of market information, lack the capacity to participate in agri-business, and they are employed in lowly paid positions (GoR, 2014).

Time allocation includes both workload (the allocation of time for productive and domestic tasks) and leisure (which captures the individual's satisfaction with the time available for leisure activities). In a household time is allocated to numerous activities such as market work for wages, work for family enterprise, and housework. Bedemo *et al.* (2013) indicated the importance of shadow wage or income, and demographic factors in affecting the time used by gender on farm labor. Adeyonu (2012) hypothesised that females allocate more time to work activities hence lesser leisure time than males. Gender differences in terms of time allocated to SWC strategies is a novel area of research.

2.3. Empirical Studies on Impacts of Women Empowerment in Agricultural Index

Measuring economic empowerment in farm households is traditionally done using WEAI (Alkire *et al.*, 2013). Several studies used WEAI to study intra-household empowerment gaps in agriculture and children wellbeing, and intra-household nutritional and wellbeing. Several studies have found that women empowerment is significantly associated with improved dietary diversity and the gender gap linked to investment and improved

nutritional status for children in Bangladesh (Malapit *et al.*, 2015; Sraboni *et al.*, 2014). Abebe *et al*. (2016) showed significant intra-household differences in extension contact, training and field day participation, and access to credit services in Ethiopia. Diiro *et al.* (2018) argued that women's empowerment in agriculture and agricultural productivity in Western Kenya has heterogeneous effects on maize productivity and farm plots managed jointly and individually by males or females.

In Rwanda, most WEAI studies focused on nutrition, dietary diversity, consumption, and agricultural commercialization with little attention on issues involving women's empowerment and SWC strategies. Malapit *et al*. (2014) baseline survey employed WEAI, the Household Hunger Scale, and women's dietary diversity 2000 and found that overall WEAI score was 0.9. The study also found that between 70% and 73 % of women had achieved adequate empowerment and gender parity respectively, and the empowerment gap between women without gender parity and the adult males was 0.15.

Under the nutrition, market and gender (NMG) analysis, Lung'aho *et al*. (2015) showed that women's empowerment to improve nutrition was influenced by four interrelated components: women's use of income for food and non-food expenditures; the ability for women to care for themselves and their families; water, health and sanitation practices; and women's energy expenditure. Haug *et al.* (2021) assessed feminization of African agriculture and the meaning of decision-making for empowerment and sustainability in six Sub-Saharan countries including Rwanda, and found that, although the women were generally not empowered, they were involved in agricultural decision-making. Onah *et al.* (2021) investigated the relationship between women's empowerment and women's dietary diversity and consumption of different food items. The production domain and women's public speaking were linked with improved likelihoods of consumption of dairy products, and fruits and vegetables including vitamin A-rich produce. Uwineza *et al.* (2021) found a positive association between women's empowerment and agricultural commercialization in the Northern Rwanda.

2.4. Project Level Women Empowerment in Agricultural Index (Pro-WEAI)

The common feature among the studies that employed the original WEAI and A-WEAI is that they were based on population surveys (Bonis-Profumo *et al.*, 2021; Quisumbing *et al.*, 2022). None of the above studies were designed for monitoring progress towards women's empowerment in a project implementation setting such as SWC program. The original WEAI has been adapted to the project level WEAI (or Pro-WEAI) suited for projects impact evaluation. Pro-WEAI includes 12 indicators (see Table 2.2) with three

domains: intrinsic agency, instrumental agency and collective agency (Malapit *et al.*, 201; Quisumbing *et al.*, 20229).

Table 2. 2. Pro-WEAI indicators and their definitions

Domain	Indicator	Definition
Intrinsic Agency	Autonomy in production	Female motivated by own values than by coercion or fear of others' disapproval
Instrumental agency	Input in productive decisions	Meets at least one of the for all of the agricultural activities a woman participate in
	Ownership of land and other assets	Owns, either solely or jointly, at least one of assets (small and large), and land
	Access to and decisions on financial services	Belongs to Household with at least one sole or joint decision about credit sources; and has access, solely or jointly, to a financial account
	Control over use of income	Has input in decisions related to how to use both income and output from all of the agricultural /non-agricultural activities they participate in
	Work balance (Workload)	Workload = time spent in primary activity + (1/2) time spent in childcare as a secondary activity
Collective agency	Group membership	Active member of at least one group
	Membership in influential groups	Active member of at least one group that can influence the community

Source: Adapted from Malapit *et al.* (2019)

Hillesland *et al*. (2021) employed eight indicators of pro-WEAI to measure the economic conditions that help facilitate empowerment (e.g., assets ownership and access to credit), as well as individual agency within an agricultural household. Pro-WEAI index has been widely applied to assess empowerment impacts of agricultural development interventions in developing economies. Despite the literature on recent studies, the use of Pro-WEAI to determine the impacts on SWC strategies is quite new in the context of Northern Rwanda.

The domain of intrinsic agency –"power within", was defined by the indicator of "autonomy in income" and measures self-help and the internal empowerment of an individual within household (Crookston *et al.*, 2021). The domain of instrumental agency – "power to"

involves decision-makingindicators and measures economic empowerment, which include input into productive decisions, ownership of land and other assets, control over use of income, access to and decisions on financial services, and work balance. This indicates it provides information on individual's access to productive resources and the capacity to make decisions about these resources (Hillesland *et al*., 2021; Malapit *et al*., 2019). The domain of collective agency –"power to", is comprised of group membership and individual's potential membership in influential groups to measure community influence and social power.

Kumar *et al.* (2021) found that improvements in women's scores, and greater control and decision-makingover income and credit, and more active involvement in groups within the community lead to improvements in women's scores. However, domestic violence and respect indicators revealed that women's groups alone may be insufficient to change deep-seated gender norms that disempower women. In Burkina Faso, Crookston *et al.* (2021) found that women's empowerment was indicated by adequacy in productive decisions, group membership and influence in groups, while men had adequacy in attitudes about domestic violence, control over use of income, and work balance. De Brauw *et al.* (2021) used a detailed panel dataset from Bangladesh to explore the influence of changes in labor supply on female labor participation and empowerment outcomes. The study observed a relatively larger use of female household labor, but a reduced share of female hired labor. In India and Bangladesh, Quisumbing *et al.* (2022) summarised three studies that focused on the impact of membership in self-help groups on women's and men's empowerment and gender equality; trainings in agricultural extension, nutrition behaviour change communication, and gender sensitization; and changes in women's roles within the jute value chain.

2.5. Farm Management and SWC Investments in Rwanda

2.5.1. Intensification and Public Investments in Agriculture

Land consolidation, crop intensification and farm management practices are key to development of sustainable production systems in Rwanda. The important roles of SWC technologies in restoring degraded landscapes and improving agricultural productivity is in line with the Rwanda agricultural intensification, a central strategy to pursue the country's goals of economic growth, food security and livelihood development (see Table 2.3).

This suggests the need to promote combined use of environmental and soil conservation management practices in the area, which combination involves use of mechanical and physical practices (terracing, contour bunds, trenches, and water retention systems), agronomic practices (fallows, hedgerows, intercropping, mulching, and tree

planting at field level), as well as fertility management practices (mineral fertilisers and organic manure) (Debie, 2021).

Table 2. 3. Land management and SWC investments under the LUC and CIP.

CIP components	Key achievement from 2013-2017
Intensification and development of sustainable production systems Sustainable natural resources, water and soil preservation	Sustainable management of natural resources, water and soil husbandry: -Land protected against soil erosion, using radical and progressive terracing (3,857,733 Ha); -70 new valley dams and reservoirs constructed
Marshland development	180,622.5 Ha additional marshlands developed
Irrigation development & legal provision of Water User Associations (WUAs)	3,889,994.3 Ha of irrigated hillside Legal provision for water user associations and tenure for irrigation systems created.
Supply and use of agricultural inputs	56000MT national fertiliser usage 15000MT Production of founded seeds Crop Intensification program expanded

Source: GoR (2013-2018)

For example, the usefulness of *Napier grass* and agroforestry specie are agronomic practices (Bizoza & De Graaff, 2012; Mutegi *et al.*, 2008) that can be combined with both physical soil management practices. For the same households, some practices can be substitutes, while others are complements (Ochieng *et al*., 2021; Shrestha *et al.*, 2021), thus farmers make trade-offs of SWC strategies during the implementation of land management, (Haggar & Rodenburg, 2021). Trade-offs arise when strategies are competing over the resources for the implementation of the practices.

Increasing crop production or production of more food on less land requires agricultural investment aimed at intensification of agricultural systems by more sustainable practices. Table 2.4 shows investment in agricultural programs in Rwanda under the CIP. These investments help to reform existing production systems, and diversify them into newer and more profitable practices by optimising the use of pesticides, fertilizers, water and other resources. The dominant approach to increase the productive capacity of the land, crops and animal resources has been through large-scale land consolidation, soil fertility management,

and the intensive use of biotechnology and external inputs (Kim *et al.*, 2022; Ndeke *et al.*, 2021).

Table 2. 4. Land management and agricultural investment costs for 5-year period

Agricultural programme investment costs	Low costs scenario		High costs scenario	
	Investment (Million RWF)	Share (%)	Investment (Million RWF)	Share (%)
Land conservation	69,296	11	183,567	15
Irrigation	190,119	29	388,242	32
Mechanization	27,311	4	210,252	18
Improve soil fertility	45,968	7	75,071	6
Seed improvement	25,029	4	29,091	2
Research & technology	23,250	4	7,621	1
Extension services	26,075	4	11,299	1
Market-oriented infrastructure	140,320	22	189,170	16
Share of maximum yield potential				
Agricultural programs	**Irrigated hillside areas (%)**	**Non-irrigated hillside areas (%)**	**Irrigated marshlands (%)**	
Land Conservation	10	10	-	
Irrigation	25	-	25	
Improve soil fertility	22	30	25	
Seed improvement	22	30	25	
Total share	100	100	100	

Source: GoR (2018). NISR/EICV5. Poverty Profile (2013-2018)

Maintaining and restoring the original state of water resources is an integral part of water management and sustainable agriculture practices through water users' associations (WUAs). The WUAs have increased equal access and participation of male and female small-scale irrigation farmers (Imburgia *et al.*, 2020). WUAs have the main role of allocating and distributing water, collecting service fees, and maintaining irrigation infrastructure (Nzeyimana, 2021). Low adoption rate of various land management and SWC practices is partly attributable to the failure of some initiatives to promote agricultural investment

(Ochieng *et al*., 2021; Ochieng *et al.*, 2017). Their intensity of use is influenced by extension services and household wealth status (Oyetunde-Usman *et al.*, 2021).

2.5.2. Erosion Control and Farm-Level Investments in SWC in Northern Rwanda

Soil degradation refers to the processes, primarily human-induced, by which soil declines in quality and thus becoming less fit for crop production. According to Alam (2014), degradation is the physical taking away of topsoil through water and wind erosion, reduced capability to store water, augmented receptiveness to overflow, and gradual absorption of soluble salts in the root zone. A high rate of soil degradation is due to the dynamism of erosive agents mainly pressure of human activities, high rainfall and steeply sloping highlands, changing demographic patterns, pressure from socio-economic development, and climate change effects that continue to put pressure on soil and water resources (Bindraban *et al*., 2012; Uwacu *et al.*, 2021). Different types of erosion in Northern Province are shown in Figure 2.3.

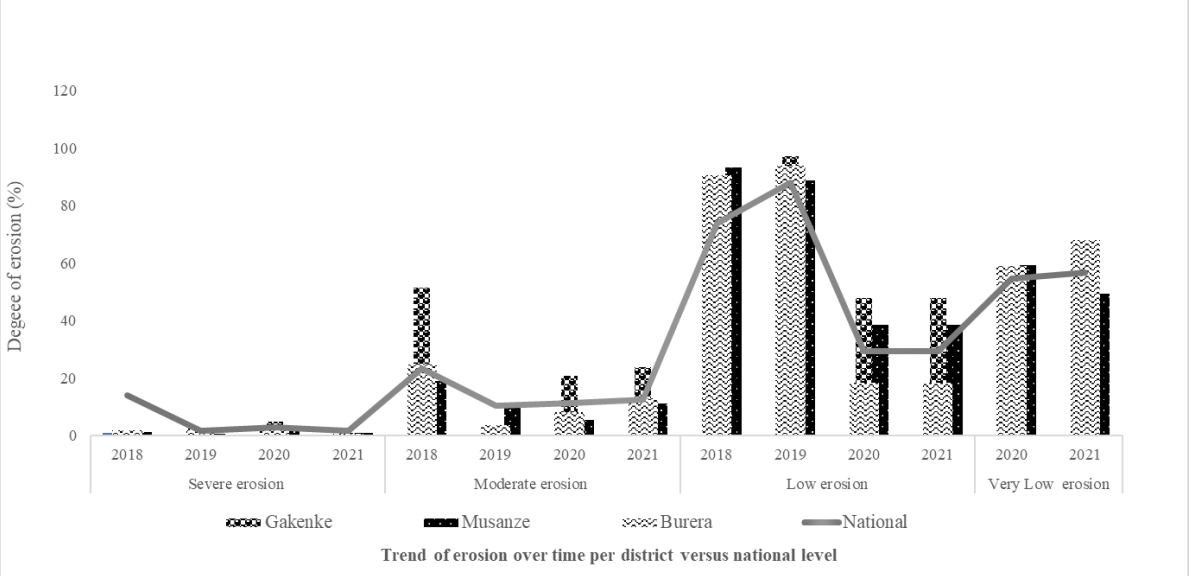

Figure 2. 2. Trends and degree of erosion per year in Northern Rwanda

Source: GoR (2021b). National Institute of Statistics of Rwanda (NISR), SAS2018, SAS2019, SAS2020, and SAS2021.

According to GoR (2021b), severe erosion (rill erosion, gully erosion, mass movement/landslides); moderate erosion (diffuse overland flow erosion, overland flow erosion); low erosion (wind erosion); and very low erosion (splash erosion) vary across districts in Northern province.

Mitigation responses have focused on environmental, physical or biological approaches to reduce soil loss mainly on steep slopes and improve cropland productivity (Du *et al*., 2021). For example, Bizoza and Opio-Omoding (2021) indicated that many farmers

invested in the farms with steeper slopes using ditches, trees/windbreak, bench terraces, progressive terraces, cover plants, water drainage, beds/ridges and water channels (Figure 2.3). The methods of SWC vary widely based on applicability to local conditions (GoR, 2021b).

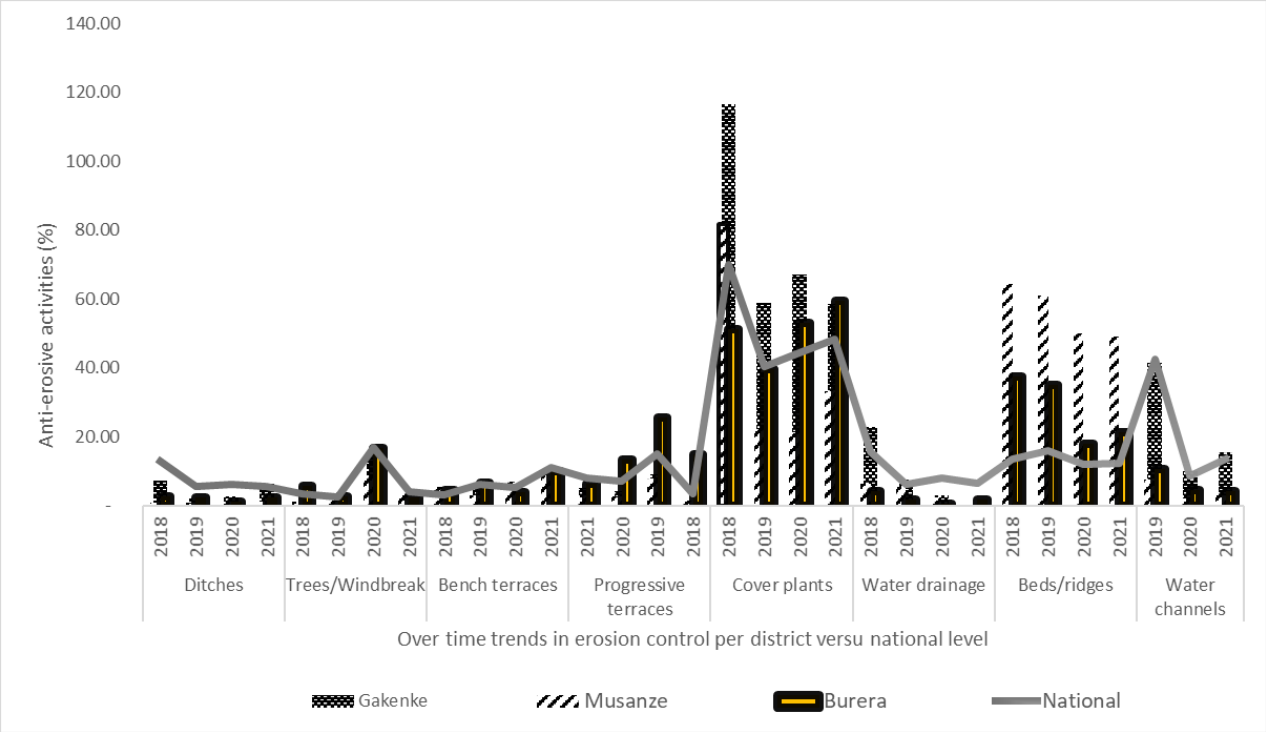

Figure 2. 3. Trends in SWC investments in Northern Rwanda

Source: GoR (2021b). National Institute of Statistics of Rwanda (NISR), SAS2018, SAS2019, SAS2020, and SAS2021.

2.5.3. Empirical Review on Gender Preferences in SWC

Gender preferences is defined as the value allocated to SWC strategies based on distinct characteristics of household members and influence on decision-making regarding various aspects in households. For instance, the value of gross output and gender of the household head are likely to influence the adoption of conservation technologies (Mugonola *et al.*, 2013). Gender differences has been considered as one of the causes of low adoption of SWC strategies (Farnworth *et al*., 2016). Decision-making in households and other control factors such as socio-demographic variables - income, age, education, marital status, and household size - can explain gendered preferences for SWC. This adds to the substantial evidence on women's differing access to productive and financial resources as shaped and reinforced by gender norms (Njuki *et al.*, 2021; Teshome *et al.*, 2016). The differences may arise also from adoption of new technologies of SWC that are developed for the needs of farmers, but are disseminated mainly with no consideration to the social and

gender norms. Such approaches increase women's burden and reduce their decision-making power and control over resources (Njuguna-Mungai *et al.*, 2021).

Other considerations for gender preferences include indicators of women empowerment and other covariates (Aravindakshan *et al*., 2021). Women empowerment can positively affect the capacity of a household to invest in SWC strategies (Adimassu *et al.*, 2012). Specifically, older household members are less involved in SWC investments than younger ones. More educated farmers are much interested in SWC investments. Household size increase SWC investment and preferences due to labor availability. Family labor availability motivate participation in SWC investment due to the considerable input family members provide for water erosion control measures and the application of fertilisers. Factors including plot level, plot location, slope steepness, and distance of plot-homestead influence perceptions, household investments behaviour and preferences. Very steep slopes may discourage investment due to expected low return on investment. In the same token, the remoter is the distance from home to the plot, the less is the investment in SWC practices due to increased transaction costs (Moges & Taye, 2017).

Institutional factors were predicted to encourage investment in SWC, and potentially influence gender preferences. These include among others, social networks, number of contacts made with extension services and availability of public or private intervention in SWC programs in the area. Social networks, as captured by household participation in agricultural production, marketing and natural resources management, is also expected to influence levels of household investment, decisions, and preferences for SWC measures. This is because social networks can promote cooperative behaviour, facilitate flow of information for SWC practices. Further, in the absence of formal credit markets, social networks facilitate saving and credit activities among farmers and improve their financial capacity to buy fertilisers (Adimassu *et al.*, 2012). Social networks also influence farmers' collaboration, preferences, transaction costs and information exchange (Läpple & Rensburg, 2011; Teshome *et al.*, 2016).

2.5.4. Links between Household Income and SWC investments

A household income consists of all receipts whether monetary or in kind (goods and services) by individual members in a given period. It covers income from both paid and self-employment; property income; and transfers (Kabubo-Mariara *et al*., 2009). Poverty distribution studies consider household income as a common measure of household welfare (Kabubo-Mariara *et al*., 2009; Wordofa *et al.*, 2021). In Rwanda, about 34.8 % of adult women live in poverty, whereas 31.6 % are adult males. The main poverty line is US$168 per

adult equivalent per year. As shown in Table 2.5, the National Institute of Statistics of Rwanda (NISR) estimated poverty using five quintiles, including US$ 90.5 for bottom quintiles, US$147, US$202, US$194, and US$736 for respectively the second, third, fourth, and top quintiles (GoR, 2017b).

Table 2. 5. Income classification per location and quintiles

Income classification		**EICV3 (RWF00/ Year)**	**EICV3 (RWF000/ Year)**	**EICV5 (RWF000/ Year)**	**% change 2014-2017**
Location	Urban	646	607	570	-6.2
	Rural	198	217	216	-0.6
	Kigali City	588	528	597	12.2
	Southern	218	264	230	-13.7 *
Province	Western	245	246	219	-11.7
	Northern	223	229	230	0.4
	Eastern	239	259	242	-6.8
Quintiles					
Poor	Q1: poor	76	85	86	0.6
	Q2	123	138	140	1.4 *
Middle-	Q3: middle	171	188	192	2.1 *
income	Q4	247	270	279	3.4 *
Rich	Q5: rich	710	734	699	-4.9
Observations		**14,308**	**14,419**	**14,580**	

Source: GoR (2018). National Institute of Statistics of Rwanda (NISR), EICV3, EICV4 and EICV5.

Note: * denotes change is significant at the 10% level or better.

Poverty measures depend on the average level of income or consumption, and their distribution in a household. Income poverty denotes those households whose income is below a designated poverty line after adjusting for household composition (Marks, 2007). The money-metric approach is often used to estimate income poverty by constructing a consumption aggregate for the entire household (Regier *et al.*, 2015). Chaudry and Wimmer (2016) indicated that income poverty is associated with lower parental capacity to invest in developmental inputs that contribute to children's development and educational outcomes. Income poor refers to households who have sufficient wealth to keep them at the poverty line,

while asset poor lack this buffer and is worse-off than the former despite both having low income. The asset and income poor people have sufficient income to achieve the minimally acceptable standard of living but do not have enough assets to protect them from a sudden drop in their income (Organisation for Economic Co-operation and Development [OECD, 2013]).

2.6. Theoretical and Conceptual Frameworks

2.6.1. Theoretical Framework

This study used botht gender analysis frameworks and agricultural household model (AHM). In Rwanda, the application of the two gender frameworks, including havard analytical framework (HAF) for people-oriented planning (PoP) and the women empowerment framework (WEF) is new in SWC literature.

Under gender framework, the WEF provides an enabling environment for women to participate equally in the development process in order to achieve control over the factors of production on an equal basis with men. While the HAF assumes that there is an economic case for allocating resources to women as well as men, POP ensures their efficient and equitable distribution of resources and services (March *et al.*, 1999).

The AHM forms the basis of analysis and review of theories and models used for the above gender frameworks within the farming household. The model assumes that farm households are price-takers. The decisions modelled include those affecting production, and the demand for inputs and those affecting consumption and the supply of labor (Singh *et al*., 1986). Previously, the AHMs were used to investigate household behaviour mainly profit-maximising, utility- maximising and risk aversion (Louhichi & Gomez, 2014). The contribution by Chaiyanov (1986) provided a theory of peasant behaviour at the level of the individual family farm. Production, labor allocation and consumption decisions were linked due to market imperfection (Taylor & Adelman, 2003). The new household economics (NHE) models were widely adopted based on Chaiyanov's ideas and provided a foundation for the study of household behaviour. The emergence of new household economics (NHE) focused on household-level decision-making whereby household resources are pooled, and allocations or organisation of production within the household are assumed to be efficient. Chiappori and Lewbel (2015) assumes that the household acts as a single unit of production and consumption which aims to maximise utility subject to its production function, income and total time constraint. The NHE theory was extended to agricultural household models and incorporated aspects of farm-household choices regarding home consumption of output, sale of output, and purchase of non-farm consumption needs (Rola-Rubzen & Hardaker, 1999).

He also postulated that the convention that members of a household behave as though they maximise a unique utility function under the constraint of a family budget is no longer the accepted one. However, the requirements of such behaviour within the household are quite restrictive and the model does not show transactions between individuals. McElroy and Horney (1981) suggested that the decision-making process should be seen as a cooperative negotiation in which each member of the household possesses his or her preferences and own alternative well-being.

Models used in gender analysis were based on the NHE. A unified household model or common preferences was used to analyse intra-household issues (Rola-Rubzen & Hardaker, 1999). The model considers the household to be composed of spouses; a man and a woman, and possibly other individuals, such as children. The spouses are assumed to participate in the decision process leading to the household's consumption, choices and resources allocation, while other household members will sometimes be referred to as non-decision makers.

The dynamics behind decision-making within the household have been questioned in recent years. Dynamic models, consisting mainly of a collective approach, recognise that preferences and decisions differ between spouses have offered a richer theoretical analysis of intra-household welfare and will be adopted for analysis of gender and SWC investments (see bioeconomic and bio-decision models in chapter one). The approach comprises cooperative and non-cooperative models that recognise specificity of individual preferences within the household making their decisions pareto efficient and acts like a black box (Chiappori & Donni, 2009). Non-cooperative models assume that individuals within the household have differing preferences and act as autonomous sub economies. The approach is well suited in developing agricultural countries where income is subject to high uncertainty. The cooperative model, rather, considers the motivations of transfer between spouses in a household or generations whereby exchange involves efficient investments and profit sharing (Zeyu, 2007).

2.6.2. Conceptual framework

Soil degradation is one of the theoretical causes leading to low farm productivity and inadequate commercialisation of crops in the area. The development of the conceptual model is based on Rola-Rubzen and Hardaker (1999)'s framework of intra-household behaviour of farm households. Additionally, the tweak-adapt-transform framework (Atwell *et al.*, 2011), bio-economic and bio-decision models address processes of participation, adaptation and adoption of SWC. As mentioned earlier, the critical issues are ineffective SWC investments

arising from unexplained gender preferences, inadequate information on factors and indicators of women empowerment that could affect investments in SWC as well as effects of these SWC measures on household wellbeing.

Figure 2.2 depicts a gendered framework for SWC as a complex system of interactions of various endogenous and exogenous factors. Socio-economic, farm and plot characteristics, institutional factors (access to roads, inputs markets, output markets; and other policy enablers) as well as domains and indicators of women empowerment provide robust information on SWC. Further, gender differences in time allocation and their differentiated preferences affect decision-makingin SWC.

Household dimensions and decisions to allocate a given resource affect the welfare of the individual members and entire household. Use, adoption or investment in SWC strategies is assumed to increase farm productivity, which in turn leads to increased household incomes, thereby reducing poverty and improving the livelihood of farmers. Increase in both farm and non-farm incomes for individual household members could enhance women empowerment whereas it promotes adoption and investment in SWC technologies. Alternatively, expenditures on production, consumption as well as others such as health, education and leisure affect the welfare of household members as well as their investment decisions.

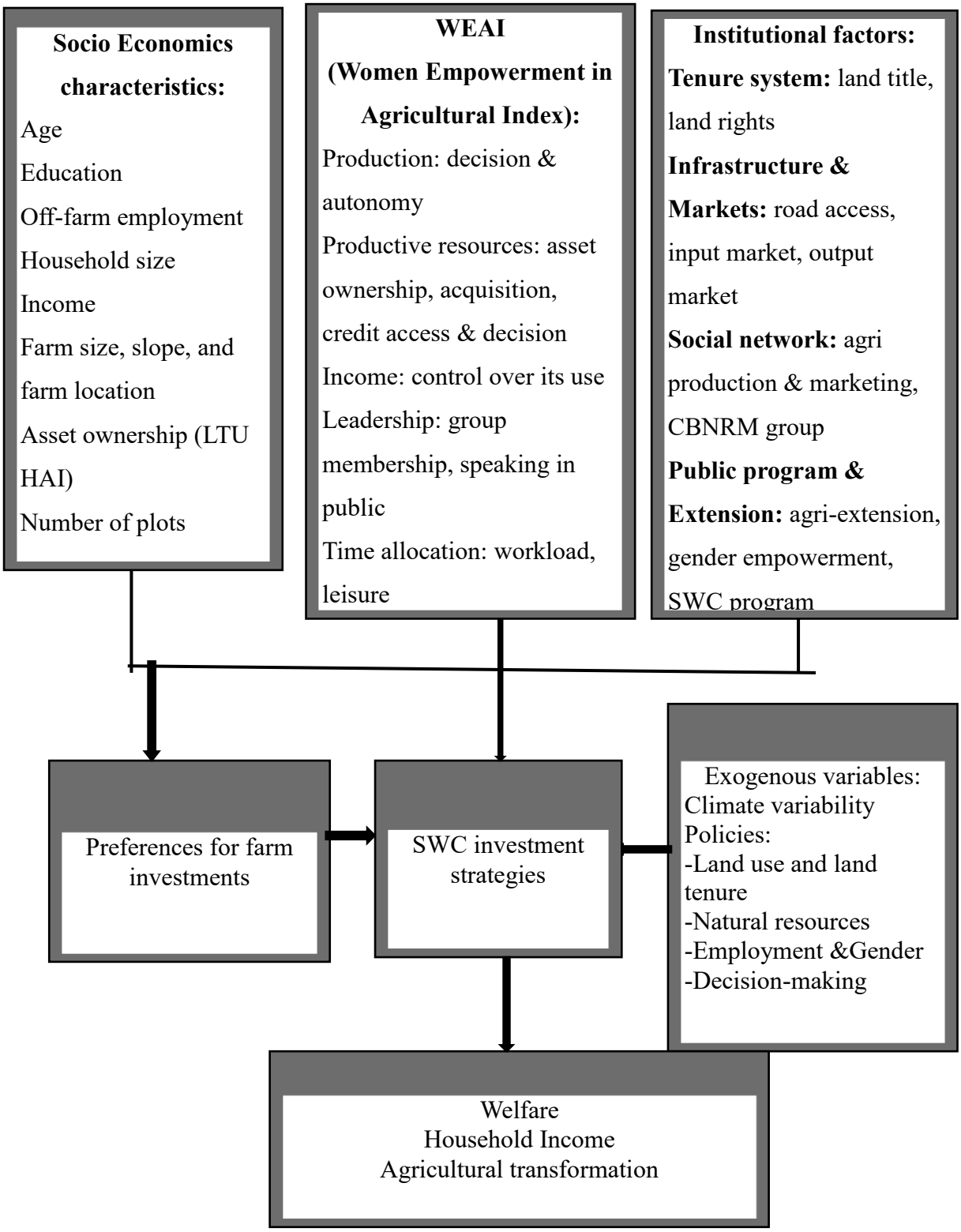

Figure 2. 4. Conceptual framework for gender analysis in SWC investments

CHAPTER THREE

TOWARDS AGRICULTURAL FEMINISATION: TRENDS IN GENDER WORK PATTERNS, PERCEPTIONS AND ADOPTION OF SOIL AND WATER CONSERVATION PRACTICES. A MIXED METHOD APPROACH

Abstract

Soil and water conservation programs have been increasingly promoted to control erosion, yet the success of their adoption has remained far below the anticipated level. SWC adoption and perception studies have largely been documented with mixed results. Trends and perceptions on gender work patterns, adoption and SWC decision-making have hardly been studied. This study used survey data collected through the multistage sampling technique from a sample of 653 respondents, of which 276 were males and 383 females. A mixed-method approach involving focus group discussions, key informants and participatory mapping was used to collect data. The data were analysed using geographical information system (GIS) mapping, thematic content analysis, descriptive statistics and t-test. GIS results show that cropland increased from 24% to 48% by 2010 at the expense of forestland which decreased up to 38 %. In 2020, forestland increased to 45% while cropland reduced to 34%. Over the years, women have increased their participation in SWC thanks to land and gender policies that granted them equal rights as men. Cultural beliefs remain a limitation for women's decision-making. On plots close to homestead, results show that organic manure, ridge farming and NPK were the mostly SWC practices adopted at 85%, 65% and 52% respectively. More women (60%) than men jointly participate in SWC decision-making, whereas more men (65%) participate in decision-making involving off-farm employment. Socio-economic and market factors significantly influence gender differences in SWC decision-making. The study recommends considering social norms in the process of empowering female farmers, initiating agricultural extension education targeting women, and promoting incentives aimed at adopting multiple SWC practices.

3.1. Introduction

Soil and water conservation (SWC) programmes have been increasingly promoted to control land degradation (particularly soil erosion), increase agricultural productivity and food security, and reduce poverty. Population increase, poor land management, vulnerable soils and hostile climates are major causes of soil erosion and land degradation (Sahoo *et al.*, 2016). Land degradation impacts negatively on the productivity of agricultural land and it contributes to the worsening of socio-economic imbalances through increases in poverty and social inequalities. Wolka *et al.* (2018) indicated that an estimated 280 million tons of crop

yield is lost annually due to land degradation in Africa. Economic losses resulting from land degradation range from US$4.3 to US$20.2 trillion of terrestrial services and between US$6.3 and US$10.6 trillion of ecological services (Prăvălie, 2021). The negative effects of land degradation on human population and agricultural development is likely to cause migration of 50 million to 70 million people by 2050 (Liu & Han, 2020; Prăvălie *et al*., 2020).

The adoption of SWC practices is one of the effective long-term strategies to conserve natural resources. The combined effects of these practices, which result from the reduction of the rates of soil erosion, increases the economic value of land (Wang *et al.*, 2020). In Rwanda, since the 1890s and before independence, farmers cultivated land around the homestead (known as *urugo*). Farms near homesteads received manure, and residues from household or harvested crops, as well as intense maintenance making the soil more fertile. On the other hand, farms and pasture land that are far from the homestead, which were relatively eroded and infertile, received less attention and care. The colonial era saw major changes in land use with intensification of the farming system. Rapid population growth, over-grazing and over-cultivation saw the emergence of new land use policies. For instance, burning bushes was outlawed and punishable by a penalty of fines and imprisonment. Crops including sorghum, beans, cassava, sweet potatoes, and Irish potatoes could make up a significant portion of the basic diet and thus occupied much of the family's farmland.

The post-colonial period was characterized by policy enforcement and reallocation of land that had been reserved for pasture to farming. This led to a major shift in the relative proportion of land devoted to crops, trees, and animals. The interaction between policy changes, economic transformations, and population growth and redistribution had important implications on the viability of the land-use system. According to Sten and Keijiro (2014), land reforms and land markets plays a crucial role in promoting agricultural intensification and food secutoiry. For instance, the commercialization of agriculture led to the intensification of land uses through reduced fallows, near-continuous cropping and labor-intensive management, etc. Commercialisation also motivated the expansion of cultivation to valleys, grasslands, marginal lands, and high-altitude regions.

Understanding trends in gendered work pattern for SWC practices is vital to reduce soil erosion and contribute to sustainable agricultural development. This is because SWC practices offer an important element to sustainable agricultural practices as a pathway for fostering agricultural feminisation through increasing resource use efficiency (Anantha *et al.* 2021; Mekonnen, 2021; Pang *et al.*, 2020). Furthermore, landscape change has been an

explanatory tool for agricultural feminisation, for example through agricultural commercialisation (Zomeni *et al*., 2008). Kawarazuka *et al*. (2022) describes feminisation of agriculture as changing labor markets that pull men out of agriculture, while increasing the share of women in agricultural labor force and their roles in management of smallholder farms. Global and local labor migration, the commercialisation of agriculture, conflict and climate change are structural factors explaining changes in gender work pattern and agricultural feminisation. Mugisha *et al.* (2019), in their study, noted that interventions and policies that increase women's access to productive resources (such as land and credit), improved seeds, fertilisers and extension services can reduce land degradation and increase agricultural productivity. Access to productive resources enables women to implement good practices of soil conservation and water conservation, and soil fertility management.

Currently, women presence in agriculture and specifically in SWC practices is rising. Females participate in conservation practices as farmers, unpaid workers on family farm as well as laborers in agricultural enterprises (Slavchevska *et al.*, 2019). Women and men have unequal access to resources, information and markets, and different rights, labor demands or food consumption (Ashby & Polar, 2019). With agricultural feminisation, gender work patterns and SWC decision-making are also changing, where women appear to be more active working as smallholder farmers or as laborers or managers on commercial farms. Thus, it is vital to consider factors of women empowerment that are embedded in resources, agency and achievement, and transforming power relations (Haug *et al.*, 2021). Such changes in SWC adoption and technology use or other behaviour arising from empowering women provides economic benefits for women themselves, the entire household and the society. Therefore, benefits from do away with gender differences in inputs access can provide women with innovative ways to allocate resources for SWC adoption and decision-making (Anderson *et al.*, 2020).

The objective of this paper is to assess trends in gender work patterns, perceptions, and adoption of SWC practices in Northern Rwanda. SWC practices have a considerable impact in reducing soil erosion and increasing food productivity (Hengsdijk *et al.*, 2005; Mekonnen, 2021; Weldegebriel *et al.*, 2021). However, studies on SWC have shown mixed results in terms of effectiveness (Mukai *et al.*, 2021; Rutebuka *et al*., 2021), adoption (Betela & Wolka, 2021; Bewket, 2007) and perception (Biratu & Asmamaw, 2016). By critically looking at the drivers of change in gendered work patterns, this study tries to connect feminisation of agriculture with trends, perception and adoption of SWC. Unlike previous studies that used econometric models such as duration analysis, joint analysis, and

multivariate probit (Beyene & Kassie, 2015; Kpadonou *et al.*, 2017; Ochieng *et al.*, 2021), this study employs a gender analysis approach and a mixed method approach involving both qualitative and quantitative techniques, and GIS mapping. To the best of our knowledge, this is among the pioneer studies that employ a combination of different methods to analyse gender differences in SWC practices in Rwanda. Including gender analysis is crucial to understand the feminisation of SWC that would inform the process of agricultural transformation.

The rest of this paper proceeds as follows. Section 3.2 describes the methodology which include study area, and study design and data collection techniques. Section 3.3 discusses the results, and section 3.4 concludes and provides implications.

3.2. Methodology

3.2.1. Study Area

Rwanda is a landlocked country located in Eastern Africa. The study area is in the Northwest volcanic (agro-ecological) zone that covers Burera and Musanze districts. Burera is located at 1° 25' S and 29° 44’ E, Musanze lies at 1°29'S and 29°38'E, while Gakenke is at 1°69’ S and 29° 26’ in Northern Rwanda. The Northwest volcanic zone is situated along Rwanda’s boarder with Democratic Republic of Congo (DRC) and the Uganda Southwest potato, sorghum and vegetable zone. Musanze and Burera comprise some parts of West Congo-Nile Crest zone and the Northern/Buberuka highland zone. Additionally, the study area extends to a small part of East Congo-Nile highlands in the Gakenke district (Figure3.1). The study area’s status as an agribusiness hub is supported by tourism activities.

Over 80 % of the population in the study area is engaged in small-scale agriculture characterised by the dominance of female labor and a gender gap in livelihood activities. This area is rich in volcanic soils and high altitude; and predominated by intense cultivation of NTAEs crops such as potatoes, beans, maize, sorghum, and cassava. NTAEs crop farming can help monetise women’s labor, link them to value chains, and improve labor standards in agriculture (Asadullah & Kambhampati, 2021). High production potentials in NTAEs make this area a distribution hub for the local, national, and East and Central Africa markets (Larochelle *et al.*, 2015). Maize supply accounts for 45 % of national maize production. Beans are the second most cultivated crop with annual yields topping 330,000 MT, and productivity stands at 1.8 MT per Ha. Adoption of climbing beans is close to 100%. The area has potential potato production (12MT/Ha) with an expected increase to 25 MT/Ha.

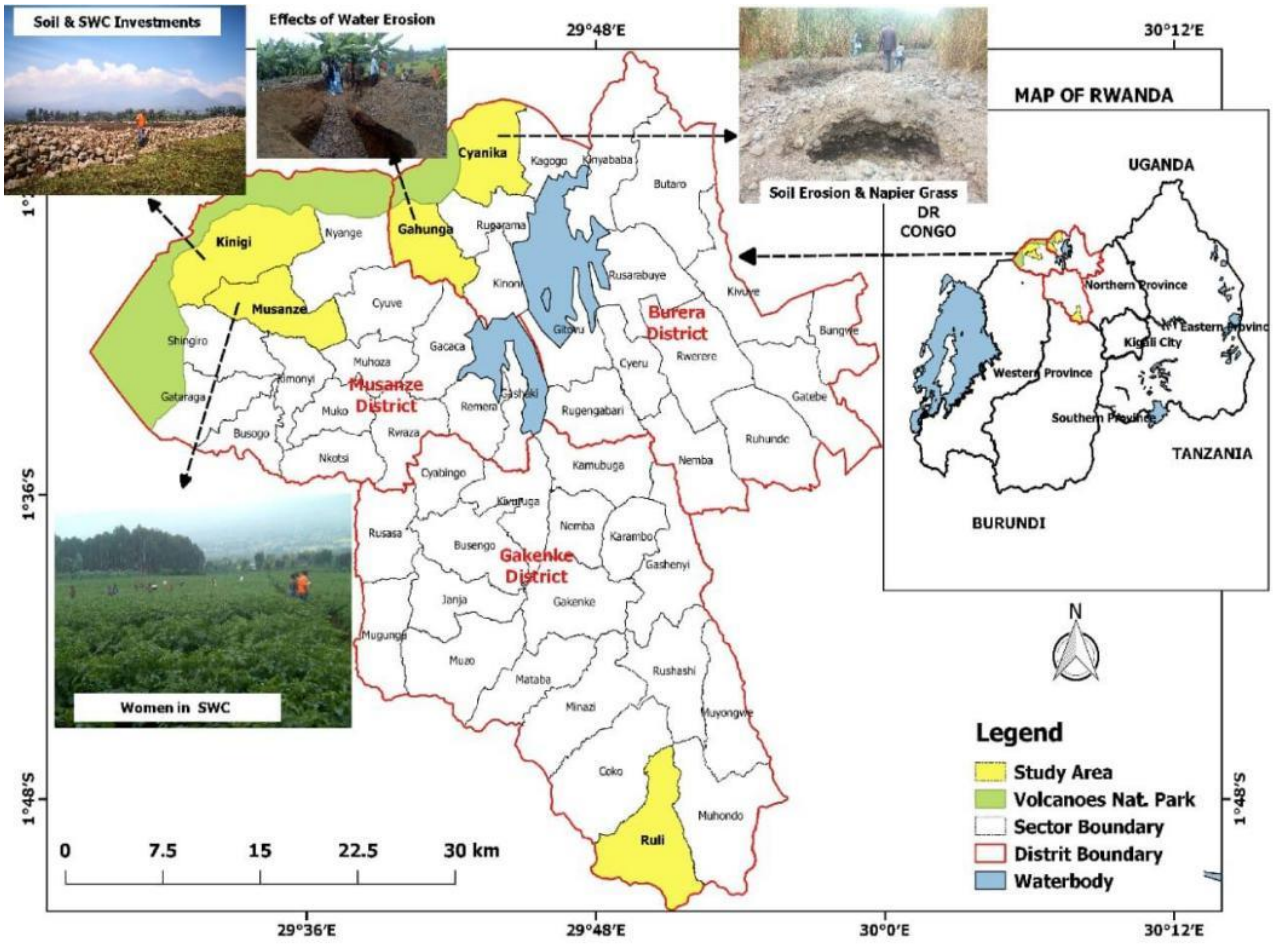

Figure 3. 1. Map of the study area

This agricultural zone is characterized by high rate of soil degradation due to high population density, unsustainable human activities, and changes in land use. As shown in Figure 3.1, over time, land conversion to agricultural land use has stood as the catalytic agent for accelerating the rate of soil erosion. Specifically, in the park farming area covering Musanze and Burera districts deforestation and vegetation clearance have accelerated the rate of erosion. For instance, soil erosion occurs through detachment, transportation, and deposition of soil particles by rain, gullies, and runoff water. Gullies constitute the most severe environmental threat in highly populated or urbanized areas with high rainfall intensity. Frequent heavy rains mixed with stones have caused high erosion risks by forming severe gullies. Gully erosion causes heavy financial losses water quality deterioration for farmers. The production system is on small and fragmented land. The study area has recorded a considerable decline in per capita availability of agricultural land per household from 3 Ha to less than 1 Ha. Rain-fed agricultural production serves as the basis for household livelihoods. Frequent heavy rains mixed with hailstones are the features of high erosion risks and severe gullies in the proximity of the volcanoes national park (VNP). The production

system is on small and fragmented land. The study area has recorded a considerable decline in per capita availability of agricultural land per household from 3 Ha to less than 1 Ha. Rain-fed agricultural production serves as the basis for household livelihoods. Frequent heavy rains mixed with hailstones are the features of high erosion risks and severe gullies in the proximity of the volcanoes national park (VNP).

3.2.2. Study Design and Data Collection Techniques

The study targeted farmers who were beneficiaries of the FATE project in Rwanda. The three districts were purposively selected based on financial availability or constraints, and the concentration of farming activities related to the production of high value crops or NTAEs. The data was collected in two rounds using a mixed method approach that involve participatory qualitative and quantitative techniques. Table 3.1 illustrates techniques employed during data collection.

In the first round that took place between August and September 2019, the study used participatory rural appraisal (PRA) techniques to collect qualitative data. The PRA techniques employed were the transect walk, participatory gender resources mapping, key informants' interviews (KIIs), and focus group discussions (FGDs). These techniques involved the identification and selection of individuals or groups of individuals that were proficient and well informed with issues of gender, SWC and agricultural transformation. The transect walks was conducted with farmer-promoters and local leaders across farms and natural landscapes. Both FGDs and participatory resource mapping techniques were conducted with separate groups of male and female. Information from KIIs were gathered from managers of local banks and micro finances, local leaders at cell or sector levels, leaders of farmer cooperatives, and representatives of non-governmental organizations (NGOs) operating in the study area.

In each administrative sector, three local leaders/farmer-promoters participated in the exercise of transect walks. Overall, 12 local leaders comprising 66% male and 34% were available for this exercise. In every sector, two sessions of both FGDs and gender resource mapping were conducted. The resource mapping, which was complemented by FGDs, helped to characterise the trend and patterns in gendered work for SWC. The number of participants per session was between eight to 12. In both FGDs and gender resource mapping, the proportion of male participants was 53 % against 47% female. Females represented 42% against 58% male KIIs. In addition, GIS data on land use and land cover was collected using remote sensing digital image processing for the last 30 years.

Table 3. 1. Data collection techniques

Data collection technique	Number	Musanze district		Burera district		Gakenke	Sex (%)	
		Musanze	Kinigi	Cyanika	Gahunga	Ruli	Female	Male
Qualitative survey								
Transect walk-participants	12	3	3	3	3	-	33.0	66.0
Resource mapping-sessions	8	2	2	2	2	-	52.0	48.0
Focus group sessions	8	2	2	2	2	-	50.0	50.0
Key informants-participants	12	4	3	2	3	-	42.0	58.0
Quantitative survey								
Number of households	422	58	62	122	139	41	47.2	52.8
Total sample-respondents	653	92	97	192	207	65	58.6	41.4

The second round that involved use of a multistage sampling technique took place from October to December 2019. Survey data was captured to complement qualitative information. The first stage involved a selection of three districts out of five in Northern Province: Burera, Musanze and Gakenke. The second stage consisted of a proportionate sampling of five administrative sectors including two in Burera, two in Musanze, and one in Gakenke. Stage three involved randomly selecting two administrative cells within the sector, and two villages were selected within each cell. In the final stage, the study used a systematic random sampling to select male and female respondents. The systematic sampling consisted of choosing every 4^{th} household from the sampling frame or the existing list of the FATE project beneficiaries. The total sample was 653 respondents, including 253 males and 400 females from 422 households.

Quantitative data were collected by fourteen recruited and well-trained enumerators through face to face interview using a multi-module questionnaire. The first module was household identification. This module helps the enumerator to locate him/her-self to the right respondents. The second module was household listing, demographics and employment. It consisted of asking questions about all household members by listing the names of all members of the household, starting with the primary respondent. The information collected were related to members of the household (either present or absent), (i) members related to household head, spouse and children, and (ii) members not related to household head or spouse; their age, education, and employment. The third module was concerned with the

application of the domains and indicators of pro-WEAI. At the end of the roster, before the pro-WEAI module, the survey asked the enumerator to identify the respondents by household type. The first type of household had both male and female adults whereas the second household had a female adult only and the third was a household with a male adult only.

Module four was concerned with the allocation of labor and time for SWC strategies in every plot owned or rented by the household during two agricultural seasons of 2019A (September 2018 – February 2019) and Season 2019 B (March 2019 – June 2019). Under this module, the time allocated to SWC practice was determined in person-days, which were defined as the total number of days worked by each household decision-makers. The respondent could estimate "how many total days spent" on each identified SWC practices in the area. As an example, if one person worked for one day on SWC practice and soil fertility management (SFM) practices, that counted as one person-day. If two people both worked for one day, that counted as two person-daysregardless whether the people are men, women or children. Eight hours per day were considered as a full day's work. Practically, "*(1) if the head of household and his wife both work for 10 days, this was equal to 20 person-days; (2) if the head of household works for 10 days, and the wife and three children each work for 5 days, it could be noted at 30 person-days; and (3) if the head of household worked for 4 hours on one day, his wife worked for 8 hours on two days and his son worked for 4 hours on a third day. This total will be 0.5 + 1 + 0.5 = 2 days.* The last module concentrated BWS choice sets for multiple SWC attributes.

Furthermore, the study used GIP remote sensing digital image processing (such as landsat TM (1990 and 2000), landsat ETM+ (2010), and landsat OLI (2020)] to quantify and generate land use and land cover over maps for the last 30 years or the periods of 1990–2000, 2000–2010, and 2010–2020. The analysis used an unsupervised pixel-based classification technique where similar pixels were grouped to establish clearly recognizable land use or land cover classes. As a result, based on physical characteristics and spectral values, the study identified five classes comprising settlement, forestland, grassland, farmland, and wetland.

Data from qualitative interviews were transcribed, coded, and categorised based on the grounded theory described in Creswell (2009) to identify response categories and develop themes. A thematic content analysis, as explained by Alhojailan (2012) was employed to identify cross-references and provide flexibility for approaching gender work patterns in SWC.

For quantitative data analysis, different approaches and econometric models were used. The study adopted descriptive analyses (with mean, standard deviations) and t-tests to

assess male and female differences in covariates and SWC decision-making. Other approaches include counting scores (disaggregated by sex of the respondent), relative attributes importance and Pearson correlations. The analysis employed various econometric models such as multinomial logit (MNL) with the maximum difference model, ISURE models and IVQR.

3.3. Results and Discussions

3.3.1. Gendered Socio-Economic Characterisation of Household Decision-makers

Gendered socio-economic characteristics of household decision makers are shown in Table 3.2. Results indicate that nearly 80% of households are headed by both male and female decision-makers. Within these households, the proportion of female decision-makers was slightly higher than male decision-makers.

Results show that male respondents earn more income, have higher education levels, access more employment opportunities, and are also slightly older than female respondents. The results show that there are significant gender differences in age, education, participation in off-farm activities, and time used to access different services. Age differences signals the increasing proportion of female-headed households due to war and the out-migration of males to towns or to neighbouring countries of DRC and Uganda. This out-migration imposes multiple burden to women, including labor and time burdens in additional to more responsibilities for working in both productive and reproductive activities, and this may limit their involvement in new technologies or paid opportunities. On other hand, Kawarazuka *et al.* (2022) argued that women may gain new opportunities from male's absence, or the families can opt to not grow crops that require considerable male labor.

Results reveal that men on average completed five years of primary education, while women completed two years. Differing education levels between men and women could lead to reduced access to extension information, which limits their ability to adopt SWC practices. Given the crucial role extension services in agricultural decision-making, Azzarri and Nico (2022) recommended increasing extension education for women to equal levels as men. Results show that men have higher participation in off-farm occupation than women.

Table 3. 2. Gender differentiated socio-economic characteristics of decision makers.

Variables	Female	Male	Combined
Household type (%)			
Male and female adult	51.5	48.5	79.88
Female adult only	100.0	0.0	20.01
Socio-economics (average)			
Household income (US$)	1,335.5 (1295.3)	1,630.6 (1405.6)	1,493.9 (1363.5)
Age of the respondents (years)	45.5 (14.9)	44.8 (13.7)	45.2** (14.5)
Years of education (number)	2.5 (3.3)	5.1 (3.7)	3.9*** (3.7)
Off-farm occupation (yes=1, 0 otherwise)	0.2 (0.4)	0.4 (0.5)	0.3***(0.5)
Access to services (average minutes)			
Access to input market	26.9 (28.6)	23.2 (25.2)	24.9*** (26.9)
Access to product market	32.8 (35.8)	25.7 (26.6)	29.0*** (31.4)
Access to farm plot	53.4 (79)	66.2 (73.1)	58.4*** (77.0)
Participation in agriculture and other economic activities (%)			
Food crop farming	62.2	37.8	633
Cash crop farming	63.3	36.7	109
Livestock raising	60.4	39.6	407
Non-farm economic activities	50.7	49.3	150
Wage and salary employment	37.8	62.2	45
SWC investment	62.7	37.3	362

***; **; * respectively indicate significant gender differences at 1%; 5% and 10%.
Standard deviations are in parentheses.

This finding confirms that women have increased share of on-farm work and likely decision-making. Men compared to women have easy access to services such as input markets, product markets, and farm plots. The results imply that, for farms managed by women, gender specific constraints may affect the technology adoption and sustainable production if socio-economic inequalities between female farmers are not addressed. The socio-cultural context of farming indicates that a female farmer is less likely to adopt yield-enhancing and soil restoring strategies (Theriault *et al*., 2014). Socio-economic and institutional barriers may refrain women's progress to invest in soil conservation and agricultural transformation (Ndiritu *et al*., 2014).

Further, results indicate that more women (about 60 %) than men (40%) participate in agriculture activities, which include food and cash crop farming, livestock keeping and SWC practices. The women's rising involvement in agriculture is an indication of feminisation of agriculture, which has impact on household food security (Asadullah & Kambhampati, 2021). Women undertake various farming activities such as clearing fields, field preparations, sowing, intercultural practices, weeding, harvesting, picking, cleaning, and drying of grains.

Results show that men and women participate equally in off-farm activities, but more men participate in wage and salary employment at 62% compared to 38% for women in the sample. Women's involvement not only in agricultural feminisation, but also in employment outside the household can improve women's power and agency and household food security. The results show that, with agricultural feminisation, women are equally getting involved in the farming business of high value crops also known as NTAE crops from preparation to harvesting and marketing. The results are consistent with the myth of feminisation of agriculture described in (Kawarazuka *et al.* (2022), who critically indicated that: " …(1) *the feminisation of agriculture, as a global trend, is associated women's greater role and increased participation in both farming and commercial agriculture; (2) Women are equally good managers, they are not less productive than men if given access to adequate resources; and women face similar challenges in agriculture as men do….".* However, the results from FGDs indicated that "*…norms and culture are the main challenges to ferminisation of agriculture and natural resources management in the area. Women are mostly in charge of low-revenue staple crops, which are characterised by uneven gender roles and responsibilities. Typically, female farmers are involved in most household chores and but, males' involvement in more farming activities is pronounced in production of value cash crops mainly Irish potatoes…"*

According to Haug *et al*. (2021), although this feminisation of agriculture can increase women's labor burden, it can also lead to empowerment of women as it was witnessed by a 48-year KII (local leader) that:

"…Both females and males equally participate and allocate tasks regarding farm investment and management practices, and decide jointly on the use of resources and incomes from the farm. However, male have greater participation in commercial activities and off-farm businesses than female…". Consistent with Ingabire *et al*. (2017), the number of women involved in farming of commercial crops in the study area has increased in the last decade. However, Bigler *et al*. (2017) argued that, despite this women's engagement, the feminisation process is limited by low market participation and negotiation power over

agricultural income. Asadullah and Kambhampati (2021) argued that, despite the new opportunity presented by the feminisation of farm work, the impact of women's participation in agriculture production and SWC on household welfare can be achieved when farming increases women empowerment.

3.3.2. Trends in Land Use Patterns and Effects on SWC

Figure 3.2 indicates land use change from 1970 up to 2020. The introduction of SWC measures started in 1970s. Results indicate that the area of forest, grassland, cropland and settlement changed significantly from 1970 to 2020. The period between 1990 and 2000 showed a decreasing trend in forestland and grassland.

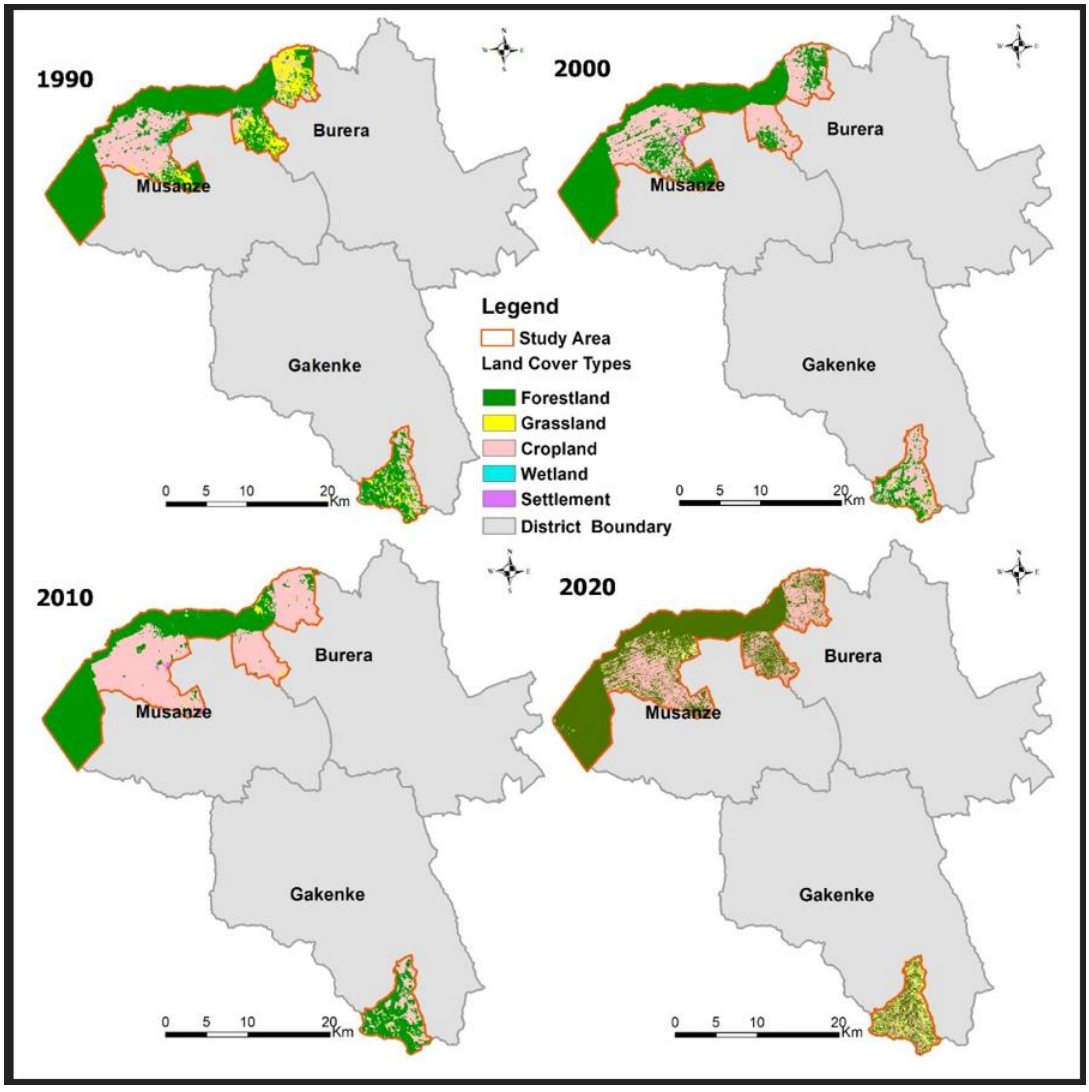

Figure 3. 2. Land use patterns and soil degradation in Rwanda

Source: Landsat TM (1970-1990 and 1990-2000), Landsat ETM+ (2010) and Landsat OLI (2020) downloaded from https://earthexplorer.usgs.gov/

This period that involved deforestation was marked by a massive land conversion from forest to commercial agriculture. However, after 2000 it showed an increasing trend in

forestland, crop land and settlement. According to the FGDs participants, "…*policy enforcement permitted the reallocation of land uses to farms resulting in a shift in the relative proportion of land devoted to crops, trees, and animals. It also motivated the expansion of cultivation to valleys, grasslands, marginal lands, and high-altitude regions…*" Maharjan *et al.* (2020) reported that due to low agricultural productivity coupled with small sizes of cropland, farming alone is not sufficient as a source of livelihood, therefore land use patterns can lead to livelihood diversification of the farmers by exploring off-farm opportunities such as labor migration, small businesses, and tourism activities.

Additionally, a 55-year old male KII revealed that: "… *Overtime, this region has been characterised by dynamics in land uses and shifts in gender specific roles in relation to changes in farming practices due to the growth of NTAE crops such as maize, beans and Irish potatoes*…". These changes in agricultural system were followed by a reduction in the production of animal products, legumes, and cereals resulting in a change in gender roles for reproductive, productive and community activities (Vallamor *et al.*, 2015). Disparities between men and women in terms of gender-assigned roles, perception and resources endowment have affected land uses over time. Additionally, female participants in FGD argued that changes in forestland, grassland, cropland and settlement were driven by multiple factors. These include: "…*the intensification of the farming system which they think it began earlier in Rwanda compared to the rest of Africa. And, the rapid population growth, overgrazing, and over-cultivation which saw the emergence of new land-use policies where the Government of Rwanda imposed penalties or fines and imprisonment for burning bushes…*"

Table 3.3 indicates that the area under forest land decreased from 54% to 51% between the periods from 1970-1990 and 1990-2000, and further decreased up to 38 %. Since 1990. the area under forest cover increased from 38% to 45% of the total land area. Results indicate that the area under grassland decreased from 15% of the total land before 1990 to 10% by 2010, and increased to 17% by 2020. The area under cropland significantly increased up to 48% in 2010 from 24% in 1990, and reduced to 34% in 2020 due to expansion of forestland and grassland. Land use change has transformed agricultural towards diversification of agricultural products and livelihoods (Thanh *et al.*, 2021). The trend in settlement increased form 1.6% (before 1990) to 3.3% in 2020. Consistent with Li *et al.* (2021), before 2000 land use transfer in Rwanda mainly consisted with the conversion of both forestland (72%) and grassland (28%) to cropland then after the transfer was balanced.

Trends in forestland, cropland and grassland was driven by the Rwanda program of villagization and resettlement in early 1997 (Van Leeuwen, 2001).

Table 3. 3. Relative change in land use for the period between 1990 and 2020.

Land cover types	Before 1990 (Km^2)	% change	1990-2000 (Km^2)	% change	2000-2010 (Km^2)	% change	2010-2020 (Km^2)	% change
Forestland	167.02	54.17	157.17	50.97	117.13	37.99	137.34	44.54
Grassland	45.10	14.63	36.06	11.69	32.06	10.40	53.34	17.30
Cropland	90.05	29.20	106.45	34.52	149.03	48.33	106.23	34.45
Wetland	1.07	0.35	1.34	0.44	1.12	0.36	1.21	0.39
Settlement	5.10	1.66	7.33	2.38	9.01	2.92	10.23	3.32
Total	**308.35**	**100.00**	**308.35**	**100.00**	**308.35**	**100.00**	**308.35**	**100.00**

Participants in FGDs and resource mapping stressed that "…*The interaction between policy changes, economic transformations, population growth, and redistribution had implications on the viability of the land-use system and increasingly smaller farms. For instance, the commercialisation of agriculture led to the intensification of land uses (with reduced fallows, labor-intensive management…".* Land use transition towards intensive and market-oriented agriculture has been linked to adoption of sustainable farm management practices such as use of chemical fertilisers and soil conservation measures, as well as improvement in overall income and livelihood security for smallholders (Burra *et al.,* 2021).

3.3.3. Gendered Work Patterns in SWC

Figure 3.3. provides a gendered work pattern in soil management and water conservation practices over time. In Rwanda, methods of erosion control dated since 1937. This period was marked by the intense adoption of soil and water practices. For instance, the introduction of rural extension officers known as "*moniteur agricole or MONAGRI"* in 1947 widened the erosion control program was followed by the adoption of infiltration ditches between 1966-1970; bench terraces in 1973; and soil fertility management and integrated agroforestry practices. Respondents revealed that gendered activities in soil conservation and soil fertility management practices have seen significant changes since 1970s. Between 1970 and 1980, more men compared to women, adopted soil conservation measures with the objective of reducing climate change effects through increasing forest cover. This period was marked by significant gender inequalities and lack of attention to men and women specific

needs, which were associated with the low use of agricultural innovations. For instance, respondents stressed that women had less decision power and access to household resources such as cows, bananas, sorghum, and related products. Meinzen-Dick *et al.* (2019) and Ndeke *et al.* (2021) argued that gender disparities in the adoption of innovations were associated with social and cultural forms of inequalities linked to social perceptions of different roles for men and women, land tenure insecurities, and women's deprived access to education and training as well as control of household assets.

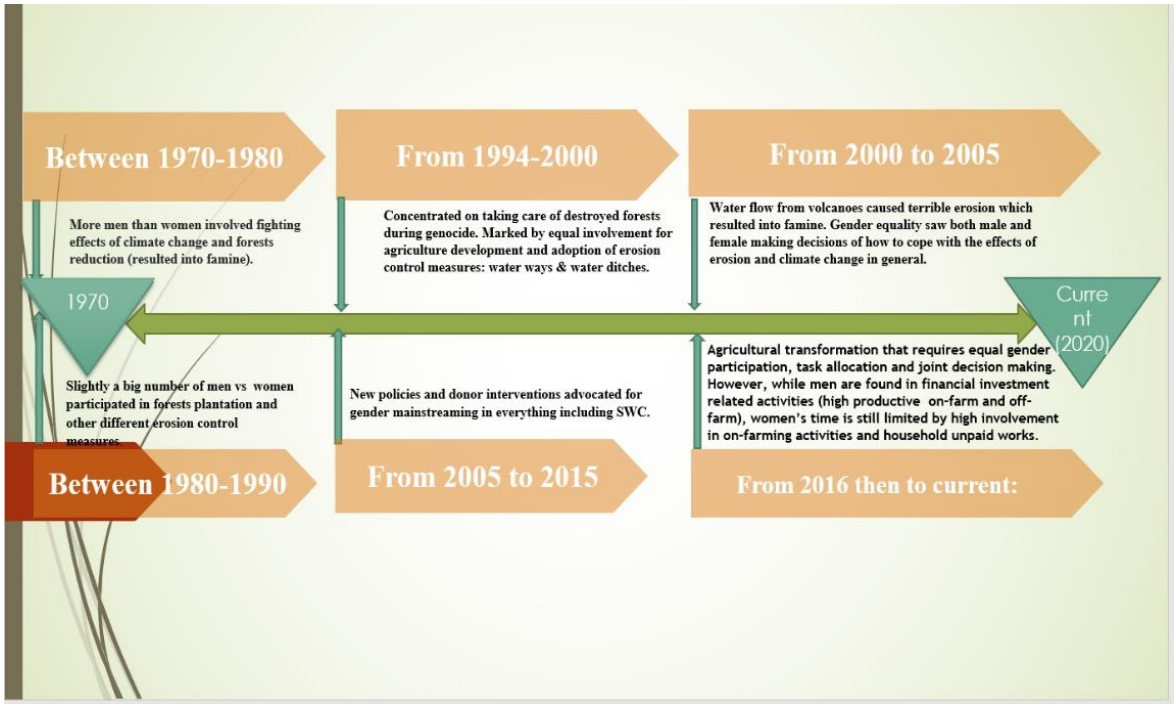

Figure 3. 3. Patterns of gender activities in SWC practices

Farmers believed that investment in conservation was one of the major strategies employed towards mitigating the threats of climate change. Forest restoration and water conservation practices (waterways and anti-erosion ditches) were introduced between 1980 and 1994, and up to 2000. These investments in SWC practices reduced exposure to shocks and climate change effects (Bezabih *et al.*, 2013). Participants in resource mapping stressed that "…*Over the years, local communities have invested a lot in restoring farmland affected by soil erosion and water flows. Famine or food shortage during this period has seen women increase their participation in forest plantations. Between 1980 and 1990, both men and women were aware of the benefits of forest plantations and erosion control measures. End of the 1980s, they controlled water flow using agroforestry, anti-erosive ditches, and Napier grasses/vetiver…".*

Respondents revealed that from 2000 and 2005 gender equality resulted in males and females making similar decisions regarding SWC through an integrated conservation

approach that has seen equal involvement of women and men in SWC to reduce effects of climate change. In Rwanda, policies regarding equal land inheritance and the success law (Law no.22/22 of 12/11/1999) have promoted improved land tenure security and equal males and females access (ownership, use) or equal right to bank loans, and decision-making regarding household properties. However, Nsengiyumva *et al.* (2022) argued that the policy changes have more significant impact in urban areas, whereas in rural areas patriarchal norms are still a hindrance to gender equality in SWC decision-makingbecause these norms facilitate more lucrative opportunities for men in comparison with women.

Respondents revealed that between 2005 and 2015, the GoR ratified land policies and donor interventions that advocated for gender equality in agricultural protection and natural resource conservation to close gender biases in land rights, access to resources, incentives, and other opportunities. During this time, an integrated conservation approach that has seen equal involvement of women and men in farm investment took place from 2010 on-wards. Due to social and economic disadvantages that women face, men were more likely to legally own land or property because they had greater resources to purchase or are favoured for inheritance. These policies, which awarded formal rights to women, helped improve their ability to buy, own, sell and obtain titles on land (Feyertag *et al.*, 2021). This is an indication that women's access to property rights makes them less economically vulnerable and provides various pathways to poverty reduction (Meinzen-Dick *et al.*, 2019). Participants indicated that: "...land policies and gender programs provided women and men with equal rights and decision-making regarding the use of income, land, and other productive resources…" According to 65-year woman, "… *national and programs have increased access to bank loans whereby both husband and wife have to decide together about their land being the collateral…*". Incentives related to secured land rights and access to inputs and finance increase adoption and investment in SWC practices (Tarfasa *et al.*, 2018).

Results also indicate that from 2005 to 2015 and after, gender mainstreaming in SWC was advocated in new policies and other donor interventions. For example, various agricultural-led reforms were adopted taking gender as a cross cutting issue. This has been critical to improve the soils in farms through investments in SWC (Aragie *et al.*, 2022). Apart from this, the feminisation process was marked by mid-term implementation plans (World Bank, 2018). Other policies were developed to cover strategies that increase land productivity (production intensification) and create more agricultural productive land. Particularly in 2006, the crop intensification program (CIP), and complementary strategies on agricultural extension services, mechanization (AMS), and the post-harvest were implemented between

2011-2020. Given the dominant position of men in the agricultural sector aimed at equal rights and opportunities in the agricultural sector and SWC, the agriculture gender strategy (AGS, 2010) formed a foundation for the process of agricultural feminisation.

Another factor that accelerated agricultural investment was the introduction of different projects including tourism and crop intensification programs. Since 2007, under the CIP and land use consolidation (LUC), specific soil conservation interventions were put in place to reduce soil degradation. For instance, a 42-year-old woman KII stated that: "…After 1990s, farmers were encouraged to form community-based organisations or cooperatives to improve our participation in agricultural farming, which increased understanding of SWC issues in Rwanda...". According to Kampmann and Kirui (2021), the role played by agricultural organisations in the feminisation of agriculture is related to the transfer of knowledge, training members on innovations, and creating value addition through the processing of agricultural produce. However, it was found that these interventions have not yet integrated aspects of gender in SWC for the mountain gorilla tourism scheme. The scheme provides 10% of annual revenues to the surrounding communities in projects related to the construction and rehabilitation of roads, water and schools, with a tiny proportion going to agricultural projects. Although women representation in the tourism activities is not significant, tourism has increased business activities whereby both male and female farmers reap benefits from it. It was indicated by FGD participants that: "…*Tourism has been one of the off-farm activities for men who work as tourist guides and use tourism revenues to support our farming activities. In addition, since the park is publicly protected, the issue of human-wildlife conflict has been quite solved because farmers are paid for crops damaged by buffaloes …*"

3.3.4. Gender Differences in Soil Conservation Decision-making

Results in Table 3.4 indicate that more than three quarters of respondents participated in joint decision-making(from some to most decisions). Less than 20% of respondents make sole (all) decisions regarding food and cash production, livestock raising and SWC investment. The results indicate that, although men and women jointly participate and make decisions, women's participation in decision-makingis at a higher rate than men. Increasing participation of women in agricultural labor force relative to men is compounded with female's increasing decision-making power on production, income use and management roles. This is an indication of much women gain greater access to agricultural income for both food crops and NTAEs by increasingly becoming primary decision makers on the farm.

Because fewer men are working in the farms, the process of feminisation of labor and farm management increasingly achieving by women.

Results show that majority of the respondents participate in joint decisions (some to most) regarding wage and salaries (87%) and non-farm businesses (68%).

Table 3. 4. Male and female in agricultural and SWC investment decision making

	Female (%)	Male (%)	Overall (%)
Food production (n=633)			
No decisions	55.1	44.9	13.2
Some decisions	53.1	46.9	41.9
Most decisions	66.4	33.6	27.9
All decisions	90.6	9.4	17.0
Cash crop production (n=129)			
No decisions	64.3	35.7	10.9
Some decisions	60.9	39.1	49.6
Most decisions	63.3	36.7	23.3
All decisions	61.9	38.1	16.3
Livestock raising (n=512)			
No decisions	68.9	31.1	25.8
Some decisions	49.5	50.5	38.3
Most decisions	63.1	36.9	25.4
All decisions	92.6	7.4	10.6
Non-farm businesses (n=210)			
No decisions	37.5	62.5	7.6
Some decisions	49.1	50.9	25.2
Most decisions	32.6	67.4	45.2
All decisions	69.6	30.4	21.9
Wage and salaries (n=45)			
No decisions			
Some decisions	28.6	71.4	12.3
Most decisions	25.6	74.4	75.4
All decisions	42.9	57.1	12.3
Investment SWC practices (n=362)			

No decisions	50.2	49.8	18.2
Some decisions	50.6	49.4	42.1
Most decisions	61.8	38.2	21.4
All decisions	90.1	9.9	18.3

Both male and female participants in FGDs believe that about 90 % of men collaborate with their wives in making land and household decisions. However, cultural beliefs remain a limiting factor for the joint-decision-making process and agricultural development. Also, there is still an uneven distribution of financial investment and household assets-related decisions. For example, in some cases, the husband can rent out land without the consent of his wife. A young aged KII said that women are involved in activities such as farming, household, and unpaid activities.

Men are involved in commercial activities, which include the supervision of farmworkers, and contract and price negotiations. Men also do trade activities, motorbike transport services, and construction while leaving women in farming works. Findings also revealed that the income derived from the non-farm business could partly finance SWC investment.

3.3.5. Gender Perception on Soil Degradation and SWC Practices Adoption

Both male and female participants in FGDs highlighted the causes of land degradation and stressed that "…*Soil degradation is due to erosion by soil and water or natural hazards triggered by heavy rainwater from the park that led to mass wasting, landslides, and severe gullies*".According to the participants, erosion takes away crops and soil nutrients and causes impairment on the quality and productivity of the farms around the park. Consistent with Atnafe *et al.* (2015), the causes of these impairments include poverty, limited access to inputs by farmers, land tenure insecurity, and limited access to financial services. Another factor is that, during transect walk both middle-aged male and female participants highlighted the following: "…*Last year (2018), there were efforts to establish SWC practices for erosion control with stone fences, AED, and waterways. In May (2019), these measures were destroyed by heavy rain with stones from the park which created wide and deep gullies*..." (Plate 3.1).

It was indicated that, in the Kinigi sector, soil erosion occurs through the detachment, transportation, and deposition of soil particles by rain, gullies, and runoff water. Participants were aware of the on-site and off-site effects of soil and water erosion on soil productivity and nutrients loss, unproductive degraded land, and a drop in potential agricultural

productivity. Gullies constitute the most severe environmental threat in highly populated or urbanised areas with high rainfall intensity.

Another factor that accelerates soil degradation and deforestation is land conversion to agricultural land. Additionally, inappropriate cultivation and land management practices cause severe sedimentation of water resources, loss of soil fertility, productivity, and health.

Plate 3. 1. Gully erosion in Gahunga, Burera District

Source: Observed during transect walk

One middle -aged man in the FGD associated severe land degradation with economic development, urbanisation, and over-cultivation. These factors have made traditional techniques such as fallow, open grazing practices, and huts (traditional houses) less effective for water retention. Severe soil degradation in agriculture causes a decrease in farm productivity and slows down commercialisation efforts. Farmer-promoters who participated in the transect walk argued that adoption of integrated soil management and water conservation comprising crops, livestock, forests, fodder, and compost reduces soil degradation. Continuous adoption of the practices and rotational grazing systems with moderate stocking rates can benefit soil health. This also serves as a source of livelihood, providing food and income while performing other social and cultural functions (Xu *et al.*, 2018).

Results indicated that majority (between 76% and 92 %) of farmers do not practise any conservation practices (*bench terraces, hedgerows, anti-erosion ditches, waterways, and*

water harvesting). Between 10 % and 20 % of farm households adopted conservation practices on a at least one plot. The adoption of conservation practices on two or three farm plots was below 10%. Farmers have limited means to establish conservation practices despite their knowledge of various conservation strategies that reduce soil degradation. The perception of specific traits of conservation practices influence their decisions to invest in SWC. A 55-year-old man in the Gahunga sector hired farm labor to remove stones brought by erosion in the form of severe gullies. "…I have paid RWF 300,000 (about US$ 350) to farmworkers to remove stones – that had been transported by erosion or rainwater - from the farm and put them into trenches. Hence, soil erosion control practices in our area require an extra investment those individual farmers cannot afford. In addition to these measures, I will need to apply for fertilisers and pesticides as soil fertility measures to improve the productivity of this plot. Hence, investment in soil erosion control is expensive…" (see Plate 3.2).

Plate 3. 2. Removing stones that had been transported by erosion from the park
Source: Observed during transect walk.

Results in Table 5.3. presents plot-level adoption of SC and SFM practices by gender.About 64% of farmers (among them 62% were female-headed households against 38% male-headed households) adopted grassed contour bank terraces or ridge farming as conservation practices making it the most applied practice in the area. "…Ridge farming with

grasses retains heavy water from the park. On the ridges, grasses can fertilise the farm, protect the soil from erosion, and provide fodder for animals…," said a middle-aged woman. These practices increase crop yields, water use efficiency, and weed control (Gosar *et al.,* 2010). Together with *Napier grass*, ridge practices can optimise soil moisture, boost crop yield, facilitate forage conservation and enhance animal performance (Maleko *et al.,* 2019). Hedgerows combined with agroforestry or fertilisers increase crop productivity and reduce soil loss (Ng *et al.,* 2008).

Table 3.5. Gendered plot-level adoption of SC and SFM practices

	SC practices (%)			SFM practices (%)		
	Female	**Male**	**Overall**	**Female**	**Male**	**Overall**
Ridge farming				**DAP**		
No practices	58.4	41.6	35.8	59.6	40.4	59.8
On at least one plot	62.0	38.0	64.2	62.7	37.3	40.2
Bench terraces						
No practices	61.3	38.7	89.2	62.4	37.6	86.8
On at least one plot	56.7	43.3	10.9	48.8	51.2	13.3
Anti-erosion ditches (AED)				**NPK**		
No practices	63.2	36.8	76.1	66.2	33.9	48.7
On at least one plot	62.0	38.0	23.9	54.6	45.4	51.3
Agroforestry				**Liming**		
No practices	62.7	37.3	91.8	61.2	38.8	95.2
On at least one plot	40.8	59.2	8.2	73.4	26.6	4.9
Hedgerows				**Organic manure**		
No practices	62.7	37.3	79.5	57.4	42.6	14.9
On at least one plot	53.5	46.5	20.5	59.5	40.5	85.1
Trenches				**Pest management**		
No practices	61.3	38.8	94.6	65.9	34.1	54.9
On at least one plot	51.7	15.0	4.8	37.5	29.2	31.5
Waterways						
No practices	63.5	36.5	77.7			
On at least one plot	55.4	44.6	22.4			

Water harvesting management			
No practices	62.7	37.3	86.3
On at least one plot	53.2	46.8	13.7

Results also reveal that 85% of respondents adopted and applied NPK (amongst them women-headed household were 66%), while 51% applied compost and organic manure as SFM practices on at least one plot. Lime, pesticides, and fertilisers (DAP and Urea) were adopted by less than 20% of household in their farms. Results show a higher concentration of these practices on the first three main cultivated plots, implying that farmers' participation in multiple SFM decreases as the number of farm plots increases. This also implies that the farther the location of the farm from home, the less the adoption of conservation and fertility practices.

Both male and female participants in FGDs revealed that: "…farms too close to the park have difficulties in managing conservation practices due to the heavy water erosion from the volcano park area. For example, in Mitobo or Nyabigoma cells of the Kinigi sector, the closest locations have no trees, ditches, and grasses such as *French Cameron* and *Napier grass*. Farmers are discouraged from planting grasses/vetiver grazed by buffaloes and other wild animals from the park since they are tasty and very nutritious. Thus, farm conservation investment in the proximity to the volcano park area is very costly as it requires wealth, money, planning, and a lot of information…"

The findings reveal that farmers were aware of the benefits of combining different soil fertility management practices and stressed that some farm plots have combined practices of soil conservation and soil fertility management. Various combinations of modern agricultural inputs, which supply nutrients in the soil, are essential for crop growth and yield (Liu *et al.*, 2020) and helps maintain the soil properties (Purbajanti *et al.*, 2019). Adoption of multiple soil fertility management practices with soil conservation practices forms an integrated SWC (Grabowski *et al.*, 2014; Kakaire *et al.*, 2016). The combined use of fertilisers and pesticides contributes to crop quality and ensures stable and high crop yields (Wang *et al.*, 2013).

3.4. Conclusion and Policy Implications

3.4.1. Conclusion

This study assessed trends and perceptions on gender work patterns, and adoption in SWC practices using a mixed method approach that include qualitative and quantitative approaches, and GIS mapping to triangulate information from various sources, as well as a

household survey data. Findings reveal that intensification of farming systems has contributed to emergence of new land use policies. Findings also show that land use practices can affect agricultural feminisation since it may alter household relations and women's participation in agricultural innovations. Information acquired from land use dynamics, policy changes and economic transformations was found to be an important factor in explaining how land conversion contributed to the intensification of land uses and agricultural commercialisation of smaller farms, which resulted in a shift in gender roles and perceptions regarding SWC as well as resources endowment.

Numerous pathways to sustainable agricultural intensification may vary by different factors including gender differences and cultural preferences and institutions. Therefore, the findings provide a connection between agricultural feminisation and women empowerment as important factors in explaining intensification of land uses of small farms. An attempt to transform farming system requires a better understanding of land-use decision-making in order to facilitate adoption of a more diversified production systems. For example, the study puts emphasis on need for gender approaches for scaling up SWC practices, including promoting packages of SWC and incentives to areas with lower SWC adoption rates to intensify their use.

Findings show that that socio-economic factors (age, education and off-farm occupation) and access to services (input-output markets and farm plots) explain gender differences and socio-economic inequalities in SWC and feminisation of agriculture. Further, education, off-farm employment and access to services were found to be key in developing agricultural innovation pathways for agricultural feminisation in SWC. Thus, the process of agriculture feminisation should be motivated by women's growing contribution to agricultural labor and making decisions on household income. This would require, for example, promotion of agricultural extension education targeting women for SWC and other off-farm investments.

3.4.2. Policy Implications

Findings indicate that, despite the myths, agricultural feminisation is important as it contributes to the transformation of women's economic roles thereby shifting them from subsistence to modern or commercial agriculture. These changes are likely to affect the division of labor in household, farm operations such as use of agricultural machinery for women, and the efficiency of agricultural output.

The study highlighted that ensuring equal opportunities for males and females to participate in agricultural feminisation is a prerequisite for gender-equitable pathways to

achieving sustainable agricultural intensification. Policies targeting women to promote awareness and sensitisations for choices of crops aimed at household food security, and SWC strategies with high value crops aimed at higher yields would contribute to the changing gender patterns in agriculture and natural resources. This study proposes designing extension programs that introduce incentives aimed at adopting multiple SWC practices on plots that are far from the households. Promoting incentives that promote women's participation in the non-farm sector would serve as a pathway to feminisation of agriculture and poverty reduction.

3.4.3. Suggestions for Further Research

The study is based on cross sectional data, but the qualitative information captured on gender work patterns involves changes over time. Given the dynamic nature of gender, both adoption of SWC practices and decision-making are dynamic and involve ongoing processes. It is important for future studies to collect data over time to assess intertemporal and changes in gender participation and decision-making in SWC. Further studies should focus on complementary and variability of conservation management and water conservation and use different economic models (bio-economic and bio-decision) which require logit longitudinal data. Longitudinal studies can also evaluate possible changes and adaptation to conservation practices that complement qualitative findings.

CHAPTER FOUR

GENDER PREFERENCES FOR MULTIPLE SOIL AND WATER CONSERVATION ATTRIBUTES IN NOTHERN RWANDA: A BEST-WORST SCALING EXPERIMENT

Abstract

Despite the dominance of female labor in agricultural production, women-managed plots are less productive as compared to men-managed plots, which implies a gender gap in agricultural productivity. Failing to account for gender preferences when designing SWC interventions may result in the slow adoption process and potentially improper policies aimed at closing the gender gap. The objective of this study was to assess gender preferences for multiple SWC attributes in Northern Rwanda. A survey using the best-worst scaling experiment was conducted on 422 households involving 653 respondents (256 male and 400 female) between September and December 2019. The study adopted a joint analysis framework combining attribute relative importance, Pearson correlation, and multinomial logit model with a maximum difference. The results with attributes importance indicated that there are gender differences in preferences for three important SWC attribute scenarios: the high scenario (between 65% and 100%); the moderate scenario (between 50 % and 65%), and the basic scenario (with less than 50% relative importance). However, the study revealed preferences heterogeneity in the relative importance of SWC attributes. Pearson correlation indicates the existence of significant complementarities and trade-offs between multiple SWC attributes. Regression results with multinomial logit show significant positive gender differences in preferences for SWC attributes related to SWC and negative preferences for household decision-making attributes. The study suggests that ensuring equal opportunities for males and females to participate in transforming agriculture, through SWC adoption, is a prerequisite and gender-equitable pathway to achieving sustainable agricultural intensification. The study advocates for gender transformational approaches for providing incentives that scale up SWC practices and promote packages of SWC practice with lower adoption rates. In addition, the study recommends increasing knowledge and extension education in SWC that aim to increase understanding of the different needs and preferences of female farmers.

4.1. Introduction

Gender has been globally viewed as a key dimension in agricultural development strategies through increasing food production and stimulating economic growth (Kpadonou *et*

al., 2017). In sub-Saharan Africa, two prevalent features of gender in agriculture are the dominance of female labor in agricultural production as women make up a higher proportion than men, and the existence of a gender gap in agricultural productivity whereby female-managed plots are between 20% and 30% less productive (Ali *et al.*, 2016; Palacios-López & López, 2015). The gender gap could be explained by gender differences in the adoption of yield-enhancing and soil-restoring technologies. Further, the agricultural productivity gap is influenced by female-specific structural (socio-economic and environmental) disadvantages, agricultural practices (differential use of inputs and use of female workers), and endowment factors (Singbo *et al.*, 2021; Theriault *et al.*, 2017). A better understanding of gender differences in preferences is vital to design proper policies for closing the gender gap in the adoption of WC practices while sustainably enhancing farm productivity.

Gender differences in control of resources and intra-household bargaining are also among the causes of gender gaps in agricultural productivity (Gebre *et al*., 2021; Peterman *et al.*, 2011). Further, persistent inequalities in income diversification create gaps in productivity and differences in human capital (Azmat & Pietrangelo, 2014). Fisher and Kandiwa (2014) argued that the gender gap does not arise because women farmers are less efficient, but because they experience inequitable access to inputs and technologies, and decision-making power. Furthermore, nature (competitiveness or risk-taking) and nurture (such as culture and environment) explain this difference in that men appear to be more competitive and less risk-averse, and hence market-oriented compared to women. An analysis of male and female preferences for multiple SWC attributes could inform the design of production, conservation, and livelihood strategies that have the potential to offset the adverse effects of land degradation (Mason-D'Croz *et al.*, 2019).

SWC measures are improved farm management practices for using, locating, and extracting resources with a significant impact on land tenure (Bjornlund *et al.*, 2019; Chimhowu, 2019). Secured land rights and land use conservation provide benefits and incentives that promote investment in SWC. Thus, the attributes of soil and water are key for overcoming land constraints and sourcing agricultural growth for food security. SWC attributes are also important for sustainable production intensification through farm consolidation and conservation by involving the use of both physical and structural measures of SWC, and livelihood strategies that entail participation in farm and off-farm activities. Yet, limited livelihood options, inadequate adoption of agricultural technologies, and poor use of conservation practices are among the causes of accelerated soil erosion and a decline in both soil nutrients and productivity. The success of each SWC strategy depends on the ability of

farming household members to make decisions about how to utilize their income from the various livelihood sources - farm, off-farm, and non-farm (Bjornlund *et al.*, 2019). Baudin and Hiller (2019) argued that the intensity and the type of contribution of family members have gender-differentiated preferences and are shaped by land and household-decision making.

Understanding gender preferences for multiple SWC attributes sheds light on strategies aimed at closing the gender gaps in agriculture. There are varied studies on the role of gender in production and conservation in closing gender gaps in agricultural productivity (Kiessling *et al.,* 2019; Thomas & Hiller, 2018), and the extensive literature on the adoption of SWC technologies, the determinants, and their impact on agricultural productivity (Betela & Wolka, 2021; Heri-Kazi & Bielders, 2021; Ojo *et al.*, 2021; Sidibé, 2005). Some empirical studies employed the sex of the household head as the gender indicator to assess gender differences in SWC adoption (Muriithi *et al.*, 2018; Ndeke *et al*., 2021). Yet, sex-disaggregated data is not indicative for analysis of gender differences in adoption and thus ends up missing the decision-making role of other household decision-makers. Other studies went beyond headship and assessed gender-differentiated adoption decisions in plots jointly managed by males and females. Such studies provided mixed findings on technology adoption decisions made jointly or separately. For instance, Kumar *et al.* (2021) and Teshome *et al.* (2016) assumed that the preferences of the household head determine household-level decisions. Nevertheless, this may lead to improper policies since male and female members have different levels of access to inputs and information, and thus their choices about SWC adoption are different and depends on household conditions and social norms dictated by culture (Doss *et al.*, 2015; Gebre *et al*., 2021).

There is a lack of empirical data on differentiated roles and preferences between males and females for SWC to inform production, conservation, and livelihood strategies important to reduce the gender gap in agricultural productivity in Northern province of Rwanda. Additionally, the widespread adoption of multiple SWC practices is still a slow process. As noted by Ward and Singh (2015), behavioural parameters motivating the slow process of SWC adoption include risk and ambiguity preferences; information and credit constraints; unsecured tenure arrangements; and unreliable supply complementary inputs. Designing proper policies for increasing the adoption of multiple SWC practices and failing to account for gender preferences may result in slow process of adoption and potentially lead to biases in estimating determinants of adoption. Magnan *et al.* (2020) used experimentally theory-based risk preferences methods and found that men's and women's preferences

differently influence farmers' adoption. An understanding of the role of family farm in household decision-making process and by household members including children, their roles regarding the adoption of multiple SWC practices would shed light on differentiated needs of family members regarding the adoption of multiple SWC measures.

The objective of the study is to assess gender preferences for multiple SWC practices. The study adds to the methodology of the BWS experiment for analysis of gender preferences in SWC in Rwanda. In comparison to other preference methods such as choice experiments (CE) and contingent valuation (CVM), BWS gives extra information about individual preference (to choose the most/least preferred attributes) of multiple SWC attributes. The study provides also a rich knowledge on heterogeneity, complementarity/synergies and substitutable SWC attributes important for policy makers to design more efficient production, conservation, and livelihood strategies.

The remainder of the paper is organised as follows. Section 4.3 describes the materials and methods and covers the study area and data collection procedure, best-worst scaling experimental design, and model specification and data analysis. Section 4.4 presents the results and discussions. Section 4.5 concludes and provides policy implications.

4.2. Methodology

Study area, and study design and data collection techniques are described in section 3.2.1 of chapter three.

4.2.1. Best Worst Scaling Experiment and Multiple SWC Attributes

This section discusses the choice and measurement of multiple SWC attributes. The study employed a BWS experimental survey to determine the differences in gender preferences for multiple SWC attributes. BWS provides ex-ante insights on alternative ways of SWC. The measurement and choice of multiple SWC attributes, as shown in Table 4.1, was based on literature about agricultural investments and SWC programs implemented in Rwanda (see section 2.5).

The study employed a BWS experiment to determine the differences in gender preferences for the SWC strategies. BWS builds on the theoretical foundation provided by Marley and Louviere (2005). It consists of ordering tasks that require survey respondents to make a selection from a collection of items by choosing the best (most preferred) and worst (least preferred) in a series of blocks that contain three or more. There are three cases of BWS depending on the complexity of options under consideration: BWS object case, BWS profile case, and BWS multi-profile case (Bridges *et al.*, 2016). BWS multi-profile is a more recent extension of CE that overcomes the limitations of the two BWS types. It provides

richer information and takes advantage of the propensity to identify extreme objects and can be used for individual-level analysis. BWS methods have gained recent extensive application in health economics (Flynn *et al.*, 2007; Mühlbacher *et al*., 2016). In the agricultural domain, BWS and latent class cluster analysis focused on agriculture marketing channels and consumer pork attribute preferences to examine the relative importance of various buyer characteristics in Indonesia (Cummins *et al*., 2016). The application of BWS in a developing country such as Rwanda is novel, and specifically its use in assessing gender preferences for agricultural investment.

Table 4. 1. SWC attributes and levels

SWC Attributes	Attribute levels	Notation
	No	NLC
Land consolidation	Yes	YLC
	Grassed ridges farming	SRC
Physical &	Hedgerows & Agroforestry	SHGA
Structural measures	Waterways & AED	SWAED
	Organic &chemical Fertiliser	UFOC
	Fertiliser & Improved seeds	UFEP
Soil fertility	Fertiliser, Improved seeds & Water	UFEPWA
management	Participation in WUAs	ULWUA
	Sole female	IMAB
Household decision	Joint male-female	IJMAF
making	Inclusion of youth	IIYOU
	Own account farming	LOAF
Livelihood sources	Off-farming	LOFFA
	Current land tenure	TCUL
Land tenure rights	Improved tenure	TIMPLA

**Note that the first letter of the attribute-level notation indicates the first letter of SWC attribute, followed by abbreviated names of levels.

This study adopted a BWS multi-profile case whereby respondents had to repeatedly choose between multiple SWC attributes and their levels in a choice. After the review and selection of multiple SWC attributes based on literature on available programs in Rwanda and before the actual survey, FGDs and KIIs were conducted to provide additional information that complemented and refined the SWC attributes. A designed experiment of

SWC attributes was pre-tested to assess the adaptability of each SWC attribute to local conditions. At the end, the study identified seven SWC attributes and 17 levels.

4.2.2. Best worst scaling experimental set up and design

The BWS experimental design consists of combining seven SWC attributes (K= 7) and their levels (L=17). SWC attributes used in the design had two, three, or four levels (L = 2,3,4). The combination of BWS attribute-levels can help to model individual-level choices in non-trivial cases involving three, four, or five choice options per choice set, and six to ten attributes varying over two or four levels. This means that our design of BWS attributes and levels was feasible and could give reliable choice sets. An example of one of the samples of multiple SWC choice card is illustrated in (Figure 4.1). Using a complete factorial design that involves an entire attribute-level combination, with LK number of scenarios, could yield 1152 maximum best-worst choices. This factorial design is, however, not practically feasible for analysis.

Multiple SWC attributes	**Option A**	**Option B**	**Option C**	**Option D**
Farm consolidated	Yes	No	No	Yes
Physical & Structural measures	Grassed ridges farming	Waterways & AED	Hedgerows & Agroforestry	Waterways & AED
Soil fertility management	Fertilizer & Improved seeds	Fertiliser, Improved seeds & Water use	Participation in WUAs	Organic &chemical Fertiliser
Household decision making	Inclusion of youth	Joint male-female	Sole female	Sole female
Livelihood source	Off-farming	Own account farming	Off-farming	Own account farming
Land tenure rights	Current land tenure	Improved tenure	Current land tenure	Current land tenure
Which SWC option would you prefer MOST (BEST)?				
Which SWC option would you prefer LEAST (WORST)?				
Which SWC option would you prefer MOST (BEST) among the remaining ones?				

Figure 4. 1. A sample of multiple SWC choice card.

The study adopted a fractional factorial approach (called orthogonal design) since it provides the best estimates. The study applied an orthogonal main-effect design plan (OMEPs) to generate SWC choice sets using IBM SPSS statistics. OMEP was an appropriate

choice for multiple SWC attributes even if unequal level replication occurs for more than one attribute (Street & Knox, 2012). In total, the orthogonal design provided 64 combinations of SWC attribute levels. Unlike for CE that generates a pair of best-worst whereby one alternative is dropped (as status quo) when generating a pseudo choice tasks, the task was to group every four alternatives in each best-worst-choice sets. Respondents were shown the best-worst choice sets (card) and requested to: (1) evaluate each of the SWC options; (2) decide which one they prefer the most; (3) decide which one they prefer the least; and (4) decide which of the remaining two SWC options they prefer the most. In short, all 64 combinations were grouped in eight profiles and 16 best-worst choice sets with 4 alternatives or option per each.

4.2.3. Model Specification and Data Analysis

The study on gender preference builds on the theoretical foundation of the best-worst scaling experiment provided by Marley and Louviere (2005) and is rooted in Random Utility Theory (RUT) by McFadden (1974). BWS method consists of ordering tasks that require survey respondents to select from a collection of items. Respondents choose the best (most important) and worst (least important) alternatives in a series of blocks. The RUT assumes that decision-makers maximize their utility by choosing their favorite SWC bundle among a set of them.

The random utility theory for BWS was presented through the maximum difference (maxdiff) model (Equation 4.1). The potential BWS choices for multiple SWC attributes were defined as a pair of best and worst. The maximum difference estimation with MNL adopted the dual coding such that best=1 and best=0. That is, the best equals 1 if a farmer chooses SWC attribute as most important (best), and the best equals 0 otherwise. Alternatively, worst equals 1 if a farmer considers an SWC attribute as least important(worst), and worst equals 0 otherwise (Mühlbacher *et al*. 2016). The error term was assumed to follow the Gumbel distribution for every pair of the best-worst choice combination.

$$P_{BW}(ii'/X) = \exp(\mu(\sum_{k=1}^{n}(\beta_i X_{ki} - \beta_{i'} X_{ki'}))/\sum_{j' \neq j} j, j' \in M \exp(\mu(\sum_{k=1}^{n}(\beta_j X_{kj} - \beta_j X_{kj'}) \quad (4.1)$$

where X_{ki} is the attribute level in the profile that is chosen as the potential best option, $X_{ki'}$ is chosen as the potential attribute with worst option; μ represents a parameter that determines the scale of the utilities. Parameter vectors β_i are associated with X_{ki} and $\beta_{i'}$ are parameter vectors associated with $X_{ki'}$.

Econometric analysis used the multinomial logit (MNL) with the maximum difference model indicates the likelihood that expresses multiple SWC attributes in terms of the BEST or WORST attribute. The probability that a respondent chooses a pair in a particular BWS choice set that maximizes the difference between the "worst attribute" and the "best attribute" was proportional to the difference between the 'best' and 'worst' item on the scale of importance (Flynn *et al.*, 2007). Based on the above equation (4.1), the maxdiff was then presented by the popular MNL-based model in Equation 4.2. MNL assumes that the utility associated with the best option is the negative of utility associated with the choice of the worst option (Flynn *et al*., 2007).The equation 4.2 indicates separate utility differences, for male and female, between the BEST and WORST SWC attributes (U^{i}_{diff} on the latent utility scale) for choice $i(i = 1,2,3 \ldots \ldots 18)$ and the 10 explanatory SWC attribute-variables (Flynn *et al*., 2008).

$$\boldsymbol{U}^{\boldsymbol{Female}^{i}_{\boldsymbol{diff}}}_{\boldsymbol{Male}^{i}_{\boldsymbol{diff}}} = \beta_{NLC}D^{i}_{NLC} + \beta_{SRC}D^{i}_{SRS} + \beta_{SHGA}D^{i}_{SHGA} + \beta_{SWAED}D^{i}_{SWAED} + \beta_{UFOC}D^{i}_{UFOC} + \beta_{UFEP}D^{i}_{UFEP} + \beta_{UFEPWA}D^{i}_{UFEPWA} + \beta_{ULWUA}D^{i}_{ULWUA} + \beta_{IMAB}D^{i}_{IMAB} + \beta_{IJMAF}D^{i}_{IJMAF} + \beta_{IIYOU}D^{i}_{IIYOU} + \beta_{LOAF}D^{i}_{LOAF} + \beta_{LOFFA}D^{i}_{LOFFA} + \beta_{TCUL}D^{i}_{TCUL} + \beta_{TIMPLA}D^{i}_{TIMPLA} \quad (4.2)$$

For the choice i, the SWC attribute chosen as BEST had its variable ($D^{i}_{swc\ attribute}$) taking value one, whereas the SWC attribute chosen as WORST had its variable taking value minus one, with the third SWC attribute taking the value zero. The "farm consolidation (YLC)" was the omitted variable and represents zero on the utility scale. The obtained base value of YLC was subtracted from all other 17 attribute values to get individual measures of importance for each SWC attribute.

Counting scores (disaggregated by sex of the respondent) and relative attributes importance, and probability ratio scale methods were used to describe multiple SWC attributes (Figure 4.2). From the mean B-W scores, the relative importance approach was employed to assess if each SWC attribute is likely important to all male and female farmers. The relative importance values were considered as probabilities that farmers choose the SWC attribute as most important (Mueller & Rungie, 2009) over other multiple SWC attributes. The attribute "inclusion of youth" decisions was assigned the highest index as the most important attribute with an interval scale of 100 and scaled by a factor to become 100%. Alternatively, the probability ratio scale methods were used to determine the mean of

individual B-W to measure attribute importance as it is mostly related to the variance-covariance matrix.

The variance-covariance matrix was calculated using individual B-W scores which contains attribute importance heterogeneity (variance) and correlation of attributes (covariance). The variance-covariance was derived from the mean and standard deviations of an individual B-W score for each SWC attribute and each respondent. The standard deviation over all respondents measured the extent to which the importance of SWC attributes varies over the sample. The greater the standard deviation the more respondents differ. Hence, variance or standard deviation were used to measure the degree of heterogeneity.

4.3. Results and Discussion

4.3.1. Count Analysis of Multiple SWC Attributes

The ranking and economic importance of multiple SWC attributes using utility scores of best and worst are presented in Table 4.3. Results show that male and female farmers chose multiple SWC attributes with the highest scores as the most important (best) attributes. These include: "own account farming" (1,487), waterways and anti-erosion ditches, inclusion of youth (1,462), no-land consolidation (1,389), and improved tenure (1,324).

SWC attributes such as off-farming (1,249), land consolidated (1,231), and improved tenure (1182) have high scores above 1000 and are regarded as average important followed by attributes with scores less than 1000. These attributes have the highest worst scores and are considered less important. Since the inclusion of youth and own-account farming are the most important attributes, combining participatory decision-making in farming could lead to the best strategy for SWC investment. Results with count analysis show farmers placed the highest scores on SWC attributes that combine land tenure, participatory households' decisions, and intensification of crops in their own-account farms or off-farm employment. Higher best-scores for own-account farming than off-farming imply that respondents give more priority to working on their farms than diversifying livelihood sources in off-farm activities. It could be associated with an increase rural youth female decision-makers in household, who become the principal operators of the farm for sustainable agricultural intensification.

Results indicate that non- consolidation (1,291) is more important than land consolidation (1,197), which implies that off-farm diversification is more important than operating in own account farm. Results signal farmers who regard land consolidation as less important may not benefit from the government crop intensification program (CIP) including easy access to improved farm inputs (seeds and fertilizers), water use (improved irrigation),

land use intensification, extension services, and post-harvest handling and storage services. Nsabimana *et al.* (2021) found that there is a price gap between consolidated and non-consolidated zones whereby CIP has increased productivity and farm incomes through land-use efficiency and market price changes.

Under physical and structural measures attributes, waterways and anti-erosion ditches are more important SWC attributes than Hedgerows and agroforestry, and Grassed ridges farming.

Table 4. 2. Count analysis of multiple SWC attributes

SWC attributes		Best scores	Worst scores	Aggregated (B-W)	Mean of ind. (B_W)	StDev ind. (B_W)	Sqrt B/W	Sqrt stand
Land consolidaion	No-land consolidated	1,389	1,291	98	-0.1	1.39	4.7	67.8
	Land consolidated	1,197	1,231	-34	0.2	1.52	3.5	49.4
Physical & Structural measures	Grassed ridges farming	667	607	60	0.1	1.44	2.6	37.0
	Hedgerows & Agroforestry	838	887	-49	-0.1	1.13	5.1	72.5
	Waterways & AED	1,485	926	155	0.3	1.67	2.9	42.2
Soil fertility management	Organic &chemical Fertiliser	629	571	58	0.1	1.20	4.1	59.2
	Fertiliser & Improved seeds	460	592	-132	-0.2	1.33	1.4	20.3
	Fertiliser, seeds & Water use	475	384	91	0.2	0.97	2.7	38.9
	Participation in WUAs	758	895	-137	-0.2	1.32	4.1	59.2
Household decision-making	Sole female	570	345	-304	-0.5	1.48	2.7	38.9
	Joint male-female	980	629	635	1.0	1.45	4.5	65.1
	Inclusion of youth	1,462	874	833	1.3	1.86	7.0	100.0
Livelihood sources	Own account farming	1,487	1,137	350	0.6	1.61	3.7	53.5
	Off-farming	1,249	1,249	-18	-0.03	1.49	4.0	56.9
Land tenure rights	Current land tenure	1,274	1,137	137	0.2	1.32	1.6	22.6
	Improved tenure	1,324	1,182	142	0.2	1.36	3.9	56.4

This implies that smallholders' consciousness of the effects of soil and water erosion may suggest the need for farmers to improve the current and widely practised grassed ridge farming as SWC practice by introducing waterways, anti-erosion ditches, and agroforestry technologies. Maleko *et al.* 2019 found that combined practices can increase crop yield, provide forage and improve livestock performance, whereas waterways and anti-erosion measures can reduce water run-off volume and velocity and direct water to large water streams.

Under household decision making, inclusion of youth was the most chosen attribute as most important followed by joint male-female and sole female decisions. Higher scores for youth inclusion indicate changes in farmers' perception about shifting from the traditional household decision-making process that values household inequalities in labor allocation and considers women and youth as the unpaid and invisible labor force. Lecoutere and Jassogne (2016) argued that incorporating young people in land ownership and participatory decision-making could reduce information and bargaining power asymmetries in smallholder farming households.

Under land tenure rights attributes, improved tenure is more important than the current land tenure. The results indicate that access to land by young men and women, as well as their involvement in land use decision-making, could be a pathway to innovation and creativity for farmers operating on their own-account farms. Therefore, improved land tenure for farmers operating on their own account farms, and increasing youth and women's participation in land consolidation would help develop new, environmentally responsible, and highly productive farming practices (White, 2015).

Under SFM attributes, the highest scores were observed for participation in water user associations (WUAs) followed by the use of fertiliser (organic &chemical), improved seeds and water use, and lastly fertilisers and improved seeds. The highest scores for participation in water user associations indicate that smallholders are concerned with water resources management for the sustainable production of crops. High scores for fertilizers combined with organic manure over others demonstrate farmers' awareness of the use of organic farming for food safety. This attribute recorded the lowest best scores but the highest worst scores. The least importance could be attributed to farmers' misperception of the distribution of improved seeds and fertilizers subsidy, whereby farmers with no full rights to land and non-CIP participants have difficulties accessing these inputs.

4.3.2. Ranking the Relative Importance of Multiple SWC Strategies by Gender

Results shown in Table 4.3 indicate the relative importance of multiple SWC attributes for the overall sample.

Table 4. 3. Ranking multiple SWC attribute relative importance

Attribute-levels	Female relative importance (N=400)						Male relative importance (n=253)					
	BW Scores	Av (BW)	Ranking Av.(BW)	Sqrt (BW)	R.importance (%)	Ranking	BW Scores	Av.(BW)	Ranking Av. (BW)	Sqrt (BW)	R.importance (%)	Ranking
No consolidation	53.0	0.04	8	1.0	26.8	11	45.0	0.03	10	2.4	75.4	3
Consolidation	-21.0	-0.02	11	3.1	84.3	2	-13.0	-0.01	13	1.6	48.7	11
Grassed ridges farming	19.0	0.03	10	1.0	26.8	11	41.0	0.1	4	1.6	48.7	11
Hedgerows & Agroforestry	-47.0	-0.1	13	2.6	70.7	3	-2.0	-0.003	12	2.4	74.6	4
Waterways & AED	130.0	0.2	3	0.7	18.9	14	25.0	0.04	9	2.2	68.9	5
Organic & chemical fertiliser	25.0	0.0	9	2.1	56.8	6	33.0	0.1	5	2.0	61.8	8
Fertiliser & Improved seeds	-103.0	-0.2	16	0.7	18.9	14	-29.0	-0.01	14	0.7	21.9	15
Fertiliser, seeds & water use	62.0	0.1	5	1.0	26.8	11	29.0	0.0	6	1.7	52.8	10
Participation in WUAs	-82.0	-0.1	15	2.0	53.6	7	-55.0	-0.1	15	2.1	65.6	6
Sole female	-149.0	-0.1	14	2.0	53.6	7	-155.0	-0.1	16	0.7	21.9	15
Joint male-female	428.0	0.7	2	2.4	64.7	5	207.0	0.3	2	2.1	65.6	6
Inclusion of youth	556.0	0.9	1	3.7	100.0	1	277.0	0.4	1	3.2	100.0	1
Own account farming	220.0	0.2	4	2.4	65.4	4	130.0	0.1	3	1.3	39.7	13
Off-farming	-21.0	-0.01	11	1.4	37.9	10	3.0	0.0	11	2.5	78.8	2
Current land tenure	85.0	0.1	7	0.7	18.9	14	52.0	0.0	7	0.9	26.8	14
Improved tenure	91.0	0.1	6	1.9	51.7	9	51.0	0.0	8	2.0	61.8	8

Overall, inclusion of youth decisions has the highest relative importance of 100 % for both males and females. Both males and females ranked household decision making, own account farming, and land tenure rights as the most chosen and most important attributes. Respondents considered fertiliser, pesticide and water (92), and no land consolidation (53) as moderately chosen most important attributes.

Female respondents placed high relative importance of 65 % and 85 % on various attributes relative to inclusion of youth. These attributes were consolidation (84.3%), hedgerows and agroforestry (70.7%), and own account farming (65.4 %). Similarly, males considered attributes such as off-farming (78.8%), no-consolidation (75.4%), hedgerows and agroforestry (74.6%), and waterways and AED (68.9%) as highly relative important as the inclusion of youth decisions.

The high important scenario combines multiple SWC attributes with respectively 0.72 times; 0.68 times and 0.65 times (at least three-quarters) as important to "inclusion of youth" decisions (with 100 %). The attributes for female are consolidation (84.3%), hedgerows and agroforestry (70.7%); own-account farming (65.4%); and joint male-female (64.7%).

The scenario indicates that combining youth decisions into joint household (male-female) decisions would improve women's participation in land consolidation for agricultural home-based own account enterprises. Hence, with the transformation process, the land consolidation process alters household relations and women's participation in agricultural innovations. As a result, there is an increase in the proportion of rural women and female household heads in agriculture as farm managers and agricultural wage laborers.

Consistent with findings of Najjar *et al.* (2022), the high important scenario is characterized by the increased involvement of women in agriculture associated with women's ownership of farmland and resources, labor and decision-making power which were previously meant for men.

In contrast, the high important scenario that combines multiple SWC attributes for males include off-farming (78.8%), no-land consolidation (75.4%), hedgerows and agroforestry (74.6%), and waterways and AED (68.9%), participation in WUAs (65.6%), and joint male-female (65.6%). This scenario reveals that the SWC attributes are most important as the inclusion of youth in decision-making justifying increased men's participation in off-farm wage work while maintaining some roles and responsibilities in the management of farm resources. However, Radel *et al.* (2012) argued that when males remain absent for long periods due to labor out-migration, married women become the farm managers and primary sources of agricultural production. Conversely, this implies that men's absence from the farm

leads to little participation in physical and structural conservation of the farm, probably because men working in off-farm can pay farm labour.

Using choice probabilities, results indicate that there are gender differences in preferences for multiple combinations of SWC attributes. As shown by the relative importance above 65%, female farmers have comparatively and highly viable preferences for SWC attributes such as inclusion of youth, consolidation, hedgerows and agroforestry, and own account farming. Similarly, men have comparatively and highly viable preferences for inclusion of youth, off-farming, no-consolidation, hedgerows and agroforestry, and waterways and AED. The results emphasize intensification and household decision-making to explain the linkages between farm investment technologies, land consolidation, and market participation. Thus, smallholders willing to invest in a farm using this strategy can maximize production and contribute to environmental sustainability.

Results indicate that the moderate important scenario comprises SWC which are times at least half (>0.5) as important as the most important attribute "inclusion of youth). For females, the attributes include joint male-female; fertiliser use (organic and chemical), participation in WUAs, and Improved tenure (>0.5). Thus, females value the combined land and household decisions as important aspects of farm management and collective action. For males, the scenario comprises attributes such as improved tenure, fertiliser, improved seeds, and water use, grassed ridges farming, and land consolidation. Therefore, men's desire for improved land and household decisions would motivate farmers under the consolidation program to participate inefficient use of farm resources.

The rest of the attributes constitute the basic scenario of SWC. The least preferred scenario comprises attributes whose relative importance is below 50 %, implying that it is less than half-important as the most important attribute/scenario. Female attributes with very low importance are current land tenure, grassed ridges farming, fertilise, improved seeds and water use, no-consolidation, and off-farming. For men, the low importance was placed on current land tenure, own-account farming, sole female decisions, and fertiliser and improved seeds. The scenario puts more emphasis on male and female differentiated preferences on the traditional gender roles in land management where land and household decision were solely made by men and women spend more time in production activities.

4.3.3. Heterogeneity of SWC Attributes Importance

The importance of measures of B-W such as mean (B-W) and standardized Sqrt (B/W) presented in Table 4.4 give the same results as the ranking methods of importance discussed previously.

Table 4. 4. Multiple SWC attributes importance and individual SWC scores

Attribute-levels	Female (n=400)							Male (n=253)						
	B	W	Agg. (BW)	Mean (BW)	Stdev (BW)	Sqrt B/W	Sqrt st.	B	W	Ag. (BW)	Mean (BW)	Stdev (BW)	Sqrt B/W	Sqrt st.
No-land consolidated	840	787	53	-0.05	1.40	3.15	84.3	549	504	45	-0.05	1.39	1.58	48.7
Land consolidated	734	755	-21	0.13	1.53	1.00	26.8	463	476	-13	0.18	1.51	2.44	75.4
Grassed ridges farming	392	373	19	0.05	1.44	1.00	26.8	275	234	41	0.16	1.46	1.58	48.7
Hedgerows & Agroforestry	509	556	-47	-0.12	1.14	2.64	70.7	329	331	-2	-0.01	1.11	2.41	74.6
Waterways & AED	918	547	130	0.33	1.66	0.71	18.9	567	379	25	0.10	1.66	2.23	69.0
Organic &chemical fertilizer	380	355	25.0	0.06	1.23	2.12	56.8	249	216	33	0.13	1.16	2.00	61.8
Fertiliser & Improved seeds	264	367	-103	-0.26	1.30	0.71	18.9	196	225	-29	-0.11	1.37	0.71	21.9
Fertiliser, seeds & Water use	288	226	62.0	0.16	0.94	1.00	26.8	187	158	29	0.11	1.01	1.71	52.8
Participation in WUAs	460	542	-82	-0.21	1.30	2.00	53.6	298	353	-55	-0.22	1.36	2.12	65.6
Sole female decisions	353	184	-149	-0.37	1.47	2.00	53.6	217	161	-155	-0.61	1.49	0.71	21.9
Joint male-female decisions	612	373	428	1.07	1.43	2.41	64.7	368		207	0.82	1.46	2.12	65.6
Inclusion of youth decisions	929	502	556	1.39	1.83	3.73	100	533	372	277	1.09	1.90	3.24	100
Own account farming	904	684	220	0.55	1.57	2.44	65.4	583	453	130	0.51	1.68	1.28	39.7
Off-farming	773	773	-21	-0.05	1.45	1.41	37.9	476	476	3	0.01	1.55	2.55	78.8
Current land tenure	772	687	85	0.21	1.26	0.71	18.9	502	450	52	0.21	1.42	0.87	26.8
Improved tenure	814	723	91	0.23	1.31	1.93	51.7	510	459	51	0.20	1.45	2.00	61.8

For instance, the intermediate mean score of attributes such as improved tenure, participation in WUAs, and fertilizer organic and chemical indicates that all-female perceived each of these attributes is medium important.

Similarly, it is indicated that all-male perceived fertiliser, pesticide and water, organic &chemical fertilizer and improved tenure as medium important.This can be a result of averaging out female or male respondents for whom it is very important with those for whom it is not important (Mueller & Rungie, 2009).

The standard deviation of the individual male and female B-W scores show that except for fertiliser, pesticide and water use, other SWC attributes have scores above one suggesting that there is all high heterogeneity in SWC attributes across all male and female respondents. Scores less than one signal that all respondents have similar perceptions and make almost the same adoption decisions on fertiliser, improved seeds, and water use. Both variance and standard deviation of individual B-W scores were high which indicate that perception and adoption decisions differ for one attributes to the other. The attributes vary over each sample and measure the importance and the degree of heterogeneity of multiple SWC practices (Mueller & Rungie, 2009). Results show that gendered differences on the relative importance of attributes such as land consolidation, waterways and AED, inclusion of youth, and own account farming. Females have a higher agreement and low heterogeneity for fertiliser, improved seeds and water use.

Results on the correlation between attributes for each group of farmers are presented in Table 4.5. A pair of SWC attributes varying together shows there are synergies, or complementary. There is a positive relationship between non-consolidation and fertiliser and improved seeds (0.31), between the inclusion of youth and Joint male-female decisions (0.34), and between improved land tenure and fertiliser and improved seeds (0.36). There is a moderate to the high negative association between various SWC attributes indicating there is a trade-off between them. A negative correlation was found between joint male-female decisions and organic and chemical fertilizer (0.36), joint male-female decisions and sole female decisions (0.37), inclusion of youth and fertiliser and improved seeds (0.40), waterways and AED and grassed ridges farming (0.54), non-consolidation and consolidation (0.62), and own account farming and off-farming (0.88).

Results with the pearson correlation matrix (Table 4.5) reveal that most attributes have a very low significant correlation which is below 0.3 ($r<0.3$). There is a low correlation since the coefficients $r<0.35$, and a moderate to high correlation since $r > 45$.

Table 4. 5. Pearson correlation matrix of multiple SWC attributes

Attribute-levels	NLC	YLC	SRC	SHGA	SWAED	UFOC	UFEP	UFEPWA	ULWUA	IMAB	IJMAF	IIYOU	LOAF	LOFFA	TCUL	TIMPLA
YLC	-0.8[3]	1.00														
SRC	0.2[3]	0.1[2]	1.0													
SHGA	-0.1[3]	0.2[3]	-0.3[3]	1.0												
SWAED	0.1[1]	0.1[2]	0.5[3]	-0.4[3]	1.0											
UFOC	0.01	0.2[3]	-0.02	-0.01	0.2[3]	1.0										
UFEP	-0.1	0.3[3]	0.2[3]	0.1[1]	0.05	-0.2[3]	1.0									
UFEPWA	0.1[3]	0.1[1]	0.2[3]	-0.04	0.1[1]	0.1[3]	0.2[3]	1.0								
ULWUA	0.3[3]	-0.1	0.05	0.05	0.1[2]	-0.1[2]	-.2[3]	-0.3[3]	1.0							
IMAB	-0.1[1]	-0.1[3]	-0.03	0.03	-0.1[3]	0.1[2]	-0.4[3]	-0.04	-0.03	1.0						
IJMAF	-0.1[1]	-0.1[2]	0.03	-0.05	-0.05	0.2[3]	-0.1[3]	0.1[1]	-0.2[3]	0.1[3]	1.0					
IIYOU	0.04	-0.1[3]	-0.1[1]	-0.05	-0.1[2]	-0.1[1]	-0.3[3]	0.1[2]	-0.2[3]	0.3[3]	0.2[3]	1.0				
LOAF	0.1[3]	0.2[3]	0.3[3]	0.1[1]	0.05	-0.1	0.2[3]	0.2[3]	-0.1[1]	-0.1[2]	0.2[3]	0.02	1.0			
LOFFA	-0.03	0.1[3]	-0.1[1]	0.1	0.1[3]	0.3[2]	0.1[3]	0.03	0.3[3]	0.05	-0.2[3]	-0.2[3]	-0.7[3]	1.0		
TCUL	0.05	0.2[3]	0.1	-0.1[3]	0.3[3]	0.2[3]	0.3[3]	0.04	0.01	-0.02	0.03	-0.01	0.1[3]	0.2[3]	1.0	
TIMPLA	0.2[3]	0.1[2]	0.2[3]	0.2[3]	0.02	-0.1	0.1[2]	0.2[3]	0.2[3]	0.04	-0.04	-0.1[1]	0.2[3]	0.1	-0.6[3]	1.0

Note: 3 p<0.001; 2 p<0.01; 1 p<0.1, implies 1 %, 5 % and 10 % level of significance respectively.

In addition, most of the correlation coefficients are statistically different from zero indicating that there is much structure because the model specification is appropriate and that there is interdependence between attributes. Results show a significant positive but low relationship between non-consolidation and fertilizer and improved seeds (0.31). This implies that preference for non-participation in land consolidation is associated with low access to improved seeds and fertilizers probably because they do not benefit from the government subsidy program, which is a pre-condition for the CIP and land consolidation in Rwanda. The study shows that there is a low synergetic relationship between the inclusion of youth and joint male-female decisions (0.34) mainly because parents and youths have a different perception of their roles in household decision making. Thus, accommodating youths in SWC production decisions may not be a priority where spouses make decisions together. Preferences for improved land tenure were positively associated with fertiliser and improved seeds (0.36). The complementary association reveals that increased access to land tenure rights provides incentives for acquiring improved seeds and fertilizers to invest in the farm. On the other hand, the low correlation indicates that there is weak competition regarding household scarce resources in adopting SWC practices.

Results also revealed that there is a moderate negative but significant relationship between Joint male-female decisions and the use of organic and chemical fertilizer (0.36), joint male-female decisions and (0.37) and Waterways and AED; and grassed ridges farming (0.40) and inclusion of youth. Results corroborate earlier findings that decision-making related to the use or application of these physical and structural measures as well as soil fertility management practices does not require the active involvement of every decision-maker in the household. In the case of NTAEs, women are taking up full managerial and labor provision roles and decisions regarding SWC adoption. Application of waterways and AED was negatively and significantly associated with grassed ridges farming (0.54). This could be attributed to farmers' lack of knowledge or extension information on the role and complementarity between these practices on the farm. Thus, they have limited information regarding the role of anti-erosion ditches in removing water from production acreage and directing them to waterways, and the role of vegetation or grasses surrounded by agroforestry trees to divert or slow down soil run-off and encourage infiltration. There are high trade-offs between non-consolidation and consolidation (0.62) and own account farming and off-farming (0.88) suggesting that respondents have low interest to participate in land consolidation programs and limited capacity to participate in diversified livelihood sources.

4.3.3. Econometric Estimation of Gender Preferences for SWC Attributes

Best-Worst results using the MNL model and maximum difference are shown in Table 4.6. The MNL model employed land consolidation (YLC) as a reference attribute to estimate individual and combined males' and females' preferences. The coefficients for each attribute level were determined relative to land consolidation.

Preferences for other SWC attributes are relative to the measure of strength and direction of land consolidation, which was omitted as a benchmark attribute in the regression (Jin *et al.*, 2019). Through the crop intensification program, land consolidation (YLC) as a reference attribute is based on the assumption that, under conditions of increasing land scarcity, sustainable intensification is essential to meet the food demand of the growing population in the study area (Jindo *et al.*, 2020). Land consolidation is also assumed to create market integration and economies of scale that increase profitability and promote household well-being (Cioffo *et al.*, 2016). Widespread promotion of more efficient and sustainable agricultural practices is required to reconcile increasing population density and increased agricultural productivity, especially in the highly populated Northern Province (Mutoko *et al.*, 2014).

Table 4. 6. MNL estimation of gender preferences for multiple SWC attributes.

Attribute-levels	**Female (n=400)**	**Male (n=253)**	**Overall (n=653)**
Land consolidation		**(Base outcome)**	
No-land consolidation	-6.05*** (0.78)	-13.29*** (4.14)	-2.99*** (0.31)
Grassed ridge farming	2.40*** (0.50)	5.41*** (2.19)	0.72*** (0.24)
Hedgerows& Agroforestry	1.84*** (0.50)	3.71**2 (1.77)	0.39* (0.23)
Waterways & AED	2.11*** (0.46)	4.30** (1.96)	0.48** (0.24)
Organic & chemical fertiliser	1.04*** (0.29)	3.34** (1.38)	0.7*** (0.22)
Fertiliser & improved seeds	0.89*** (0.28)	2.72*** (1.02)	0.08 (0.28)
Fertiliser, seeds & water use	0.46* (0.26)	1.10 (0.75)	-0.11 (0.23)
Participation in WUAs	0.69*** (0.26)	2.09** (0.80)	-0.24 (0.25)
Sole female decisions	0.02 (0.15)	-0.14 (0.37)	-0.46* (0.25)
Joint male-female decisions	-0.68*** (0.18)	-1.74*** (0.67)	-0.4* (0.21)
Inclusion of youth decisions	-0.02 (0.13)	0.13 (0.36)	-0.51 (0.23)
Own account farming	1.63*** (0.47)	1.56 (1.10)	0.87*** (0.25)

Off-farming	0.76* (0.44)	-0.88 (1.27)	0.63*** (0.26)
Current tenure	1.34*** (0.40)	2.86** (1.33)	0.76*** (0.25)
Improved tenure system	1.15*** (0.39)	2.96** (1.35)	0.73*** (0.25)
_cons	- 4.17** (2.13)	-5.72 (5.10)	-4.04*** (0.97)
Log likelihood = -313.13886:	LR chi2(17) = 245.14	Prob > chi2= 0.0000	Pseudo R2= 0.2813

Note: *** p<0.001; ** p<0.01; * p<0.1, implies 1 %, 5 % and 10 % level of significance respectively. Standard errors are in brackets

Overall, the Log-likelihood ratio, the chi-square test, and the p-value indicate that the fitness of the MNL model was good. The values of Log-likelihood (-313.13886) and chi-square test (Prob > chi2 = 0.0000) were significant at 1 %, which is an indication that the overall fitness of MNL model was good.

Results reveal that non-land consolidation and land consolidation attributes exhibit a negative association and are statistically significant at 1%, meaning that both male and female farmers who believe land consolidation is important are less likely to believe non-consolidation is important. Men have more preferences than women (-13.29 to -6.05) to participate in activities that are linked with non-consolidation and other forms of off-farm employment rather than consolidating their lands for agricultural activities.

Results indicate that attributes related to physical and structural measures, and soil fertility management attributes are statistically significant and positively associated with land consolidation. It implies that both males and females highly prefer the said attributes compared to other attributes. Results signal that both males and females have an increasing desire to transition farming methods from increased productivity to sustainable production. The transition pathways aim to shift the farming system from its current norm through different farm structural changes to bring about enhanced and sustainable food production (Bayne & Renwick, 2021). Additionally, it could be explained by farmers' understanding of the importance of integrated and innovative use of improved management techniques for advancing sustainable crop production.

Physical and structural measures are significant and positively linked with land consolidation. However, waterways and anti-erosion ditches, and grassed ridge farming are more preferred attributes than hedgerows and agroforestry. Results signal that both males and females are willing to improve the current farming and conservation practice commonly adopted with waterways and anti-erosion ditches as soil conservation and water protection

measures to improve crop yield and soil water content. Nevertheless, they both have low awareness of the use of hedgerows and agroforestry trees in their farms/ridges. Integration of these SWC practices improves crop productivity, plant height, and yield performance on a sustainable basis (Islam *et al*., 2017). These combined approaches can also reduce soil loss, maintain vegetative soil cover and replenish soil organic matter. Furthermore, these soil and water erosion control techniques can boost resource use efficiency in the sustainable production of crops (Shrestha *et al.*, 2021).

Soil fertility management attributes which include organic and chemical fertilizer, fertiliser and improved seeds, and participation in WUAs, are statistically significant and positively associated with land consolidation for both males and females. Preference for use of fertilizers is in line with the positive impact of the land consolidation titling policy on farmers' fertilizer use, and access to fertilizer subsidies (Hu *et al.*, 2021). It could imply that farmers have adequate knowledge of the positive effects of agricultural inputs in maintaining the soil properties, increasing productivity, and improving crop storage. Integrated application of both organic and inorganic sources of nutrients could efficiently enhance soil fertility, thereby achieving maximum yield (Liu *et al.*, 2020). Similarly, both male and female farmers show their desire for collective action through community water user associations to manage water from the volcanoes by digging holes, creating ditches, and constructing water channels. However, fertiliser, improved seeds, and water use were significant for females only at 10%. While this attribute is not significant for men, low preferences compared to others could be associated with a lack of or inadequate access to irrigation facilities due to high costs in the area.

Results show that, under household decision-making, joint male-female is significant and negatively associated with land consolidation. Male and female respondents are dissatisfied with the current household decision-making approach for agricultural intensification. The negative desire for joint male-female or inclusion of the youth attributes suggests their need to move from the present scenario towards a participatory household decision-making approach that accommodates women and mostly the youth. Zulu *et al.* (2021), argued that challenges that females and youth are facing for inclusive agriculture sustainable intensification include limited access to land and capital, limited involvement in decision making, and negative attitudes in the communities (mainly for the youth). However, decisions about sustainable agricultural intensification practices are not taken independently of other farm household decisions but are intrinsically linked. Supporting smallholders' decision-making is important for managing trade-offs and synergies for sustainable

agricultural intensification (Adolph *et al.*, 2021). Negative preferences for joint household decision-making suggest the need for awareness of the benefits associated with bargaining power. The results also deviate from the conceptualization that farm households should act as collective action institutions that make interactive decisions about investment (Lecoutere & Jassogne, 2016).

Results show that both own-account farming and off-farming are significant for females and positively related to land consolidation. Female preference for both livelihood activities may result in classifying female farmers into those who turn agriculture into a proper full-time business by fully allocating labor on their farms and those who tend to diversify their livelihood off-farm and can use part of their off-farm income to invest in sustainable agricultural intensification. Females who indicated that they individually prefer on-farming activities have the desire to engage in decisions regarding farm production and markets. According to Melketo *et al.* (2020) and Rashidin *et al.* (2020), a considerable share of off-farm employment to household farm income contributes to increased farm investment and agricultural productivity.

Results also indicate that both the current tenure system and the improved tenure system were significant and positively linked with land consolidation. Overall male and female preferences for land tenure rights could be an indication of their consciousness and awareness of dynamics in land laws that would provide equal rights to land ownership for young women and men. It could be also explained that both males and females recognize the centrality of land to development and promote tenure rights and equitable access to land, fisheries, and forests. Hughes and Kaiser (2017) argued that inadequacy for land use rights and decision-making authority of women over land may compromise participation efforts in consolidation. Secure land rights and understanding of land issues in Rwanda are among the incentive mechanisms aimed to improve farm productivity and promote specialization in farming (Alobo, 2019).

4.4. Conclusion and Policy Implications

The study assessed gender preferences for multiple SWC attributes. The BWS experiment survey was conducted on the beneficiaries of the FATE project in Northern Rwanda. The study adopted a joint analysis framework combining count analysis, attribute relative importance, pearson correlation, and multinomial logit model with a maximum difference. Overall, the study revealed preference heterogeneity in the relative importance of SWC multiple SWC attributes, and the existence of significant complementarities and trade-offs between these attributes. Consistent with findings from count analysis, the study revealed

that there is no particular set of SWC attributes for the adoption of sustainable agricultural intensification. This suggests the need for scaling up SWC and providing incentives for promoting each package of SWC practice with lower adoption rates for the intensification of their use. Thus, attributes of land consolidation and crop intensification meet the assumption that sustainable intensification is essential to meet the food demand of the growing population, mainly under conditions of increasing land scarcity. Moreover, findings with MNL indicates that both male and female have positive preferences for multiple SWC practices, whereas they have negative preferences for household decision-making attribute. This is an indication that ensuring equal opportunities for males and females for achieving sustainable agricultural intensification is a prerequisite for gender-equitable pathways to transforming agriculture. According to Ochieng *et al.* (2021), numerous pathways to sustainable agricultural intensification may vary by different factors including gender differences and cultural preferences and institutions.

Findings on gender differences for SWC attributes scenario provides understanding on the transitions from the current norm of farming system to farm level structural changes involving landscape changes, land consolidation and intensification of land use. The link between sustainable intensification of agriculture and farm level structural changes has implications to food security and poverty reduction. The findings on SWC scenarios align with literature that supporting smallholders' decision-making is important for managing trade-offs and synergies for sustainable agricultural intensification. This implies the need for more strategic, medium to long-term SWC investment decisions focusing on key aspects of farm structural changes mainly farm size and specialisation or production intensity of the farming system.

The present study was based on cross-section data and MNL to assess preferences for multiple SWC attributes. With the MNL model, the study shows that farmers have heterogeneous preferences for unobserved attributes but common preferences for observed SWC attributes. However, individual male and female preferences are asymmetric and heterogeneous. Further studies should use BWS data and focus on mixed logit, random parameter, or latent class to allow heterogeneity in choice parameters.

CHAPTER FIVE

WHAT IS THE EFFECT OF WOMEN EMPOWERMENT ON LABOR TIME ALLOCATED TO SOIL AND WATER CONSERVATION STRATEGIES? EMPIRICAL EVIDENCE FROM NORTHERN RWANDA

Abstract

Despite Rwanda's high score (0.91) of the women empowerment in agricultural index (WEAI), key constraints for women such as heavy workload, poor access to and decision on credit, and lack of control over use of income still persist. Empowering women for sustainable land management is among the most effective methods of reducing the effects of land degradation through the resultant investment in SWC technologies. Yet, the contribution of of women empowerment to SWC strategies has not been addressed in Rwanda. To assess these effects, the survey analysed both plot-level and pro-WEAI data from 653 individual household members comprising 256 male and 400 female respondents in Northern Rwanda. Data analysis was performed using independent t-test and the ISURE model. Findings show that female use between 221.04 and 2709.01 additional labor-hours for invisible SWC investment and SC practices compared to male. Further, compared to men, women use lesser time for soil fertility management (-17423.46 labor-hours), integrated soil management and water conservation (-14,210 labor-hours), and financing SWC investments (-248.51 labor-hours). Results also reveal that investment in integrated soil management and water conservation and financing SWC investments have less costs and more comparative advantage in producing non-traditional agricultural export crops. Empirical results indicate that while women's empowerment indicators related to intrinsic agency, instrumental agency and collective agency have mixed effects on labor time allocated to SWC strategies, there was no significant effects on financing SWC strategies. Furthermore, women's control over use of income has no significant effects. Socio-economic characteristics, mainly education, main occupation, and access to institutions and markets influence the labor time allocated to SWC strategies. The findings are relevant for designing economic strategies and gender transformative approaches to bolster women's empowerment in SWC and to create just pathways to agricultural feminisation.

5.1. Introduction

Soil and water are vital resources in agricultural production. Yet, land degradation in the form of soil erosion is one of the most recurrent problems affecting the globe (Wasie *et al.*, 2020). Productivity gains cannot be realised unless the drivers of land degradation are

addressed (Okpara *et al.*, 2019). Land degradation is gendered and closely tied to gender biases in land rights, access and control of assets, resources and information, employment opportunities, opportunity to participate in decision-making, and the distribution of cost-benefits linked to SWC investment (Lambrecht *et al.*, 2017; Okpara *et al.*, 2019). As rural male and female farmers depend on the productivity of the farm for their subsistence livelihoods, the low adoption of SWC remains a serious concern in the smallholder farming system. Gender preferences might affect the uptake of SWC technologies and efforts to close the gender gap in agricultural productivity (Mponela *et al*., 2021).

Empowerment is defined as a process to change the distribution of power between men and women and their ability to make strategic life choices (Kabeer, 2001; Lecoutere & Wuyts, 2021; Tandon, 2016). Gender equality and empowerment of all women and girls have been identified as priority pillars among the 17 sustainable development goals (SGDs). Moreover, gender equality and women's empowerment are important goals from a human rights perspective, particularly for increasing agricultural productivity and reducing poverty (Quisumbing *et al.,* 2022). Empowering women for sustainable land management (SLM) is seen as an important pathway to combat and even reverse land degradation through the adoption of SWC technologies. Successful gender empowerment strategies can lead to participatory decisions and equal access to resources, which could accelerate the adoption of labour-saving technologies and practices to reduce rural women's domestic workload (Diiro *et al.*, 2018).

Women's empowerment encompasses all means and ends of altering relations of power and narrowing the gender gap. It also means enabling women with education, employment, decision-makingand better health in view of an equal and just society (Pankaj *et al.*, 2021; Presser & Sen, 2000). International development organizations have incorporated empowerment objectives and integrated activities designed to empower women into their agricultural projects and programs. Table 5.1 shows the project level women's empowerment in agricultural index (Pro-WEAI) adapted from the original WEAI (Alkire *et al*., 2013; Malapit *et al.*, 2017) for monitoring progress towards women's empowerment for SWC strategies under the FATE project in Rwanda.

Table 5. 1. Domains and indicators of pro-WEAI

Domain	Indicator	Definition
Intrinsic Agency	Autonomy in production	Female motivated by own values than by coercion or fear of others' disapproval
Instrumental agency	Input in productive decisions	Meets at least one of the for all of the agricultural activities a woman participate in
	Ownership of land and other assets	Owns, either solely or jointly, at least one of assets (small and large), and land
	Access to and decisions on financial services	Belongs to Household with at least one sole or joint decision about credit sources; and has access, solely or jointly, to a financial account
	Control over use of income	Has input in decisions related to how to use both income and output from all of the agricultural /non-agricultural activities they participate in
	Work balance (Workload)	Workload = time spent in primary activity + (1/2) time spent in childcare as a secondary activity
Collective agency	Group membership	Active member of at least one group
	Membership in influential groups	Active member of at least one group that can influence the community

Source: Adapted from Malapit *et al.* (2019)

Pro-WEAI is based on a weighted adequacy count across 12 indicators. The 12 indicators measure three domains corresponding to intrinsic agency, instrumental agency, and collective agency. The indicators of the intrinsic agency are autonomy in income and gender attitudes (self- efficacy, attitudes about IPV against women, respect among household members, measures of self-respect and the internal empowerment of an individual). Hillesland *et al.* (2022) indicated that instrumental agency measures economic empowerment, which includes an individual's access to productive resources and the capacity to make decisions about these resources. The indicators of instrumental agency are - input in productive decisions, ownership of land and other assets, access to and decisions on financial

services, control over the use of income, and workload. The collective agency domain includes group membership and membership in influential groups indicators, and an individual's community influence and social power (Malapit *et al.*, 2019).

SWC refers to the practices of halting degradation, the rehabilitation and restoration of degraded soils and water and their optimal use. The Uptake of SWC as sustainable land management practices offers promise for promoting women's empowerment and contributing to poverty reduction (Diiro *et al.*, 2022; Jones *et al.*, 2019). As women become increasingly empowered in decision-making, sustainable intensification can be achieved by harnessing the positive aspects of the adoption of SWC (Mponela *et al*., 2021). There is a growing recognition that the widespread adoption to change or innovation is shaped by social relations and negotiations among actors, including those living in the same households (Crossland *et al.*,2021). A more participatory intrahousehold decision-making process is expected to empower women by increasing their voice and effective decision-making power, and through reducing collective action problems which may compromise efficiency and equitable sharing of costs and benefits of agricultural households (Lecoutere & Wuyts, 2021).

Household decision-making reflects a woman's control over practical decisions in her life, such as her ability to invest in SWC strategies (Porth *et al*., 2021). Previous studies have focused on the influence of gender roles on responsibilities and participation or adoption in agricultural production and natural resources conservation (Lambrecht *et al.*, 2017; Ndagijimana *et al.*, 2019). Despite this vast literature on adoption and gender differences in the adoption of SWC practices, studies on the role of women's empowerment in influencing the adoption of SWC in Northern Rwanda are scanty. Further, there is no empirical evidence regarding the effects of women's empowerment indicators on the level of SWC investments. Furthermore, the role of institutional factors and farming household characteristics in explaining the level of SWC investments in Rwanda's volcano region is not well understood.

Different interventions have been implemented to increase women's economic empowerment in resource-poor settings in Rwanda. An NMG study linked women's empowerment with four interrelated components: women's use of income for food and non-food expenditures; the ability of women to care for themselves and their families; water, health and sanitation practices; and women's energy expenditure (Lung'aho *et al.*, 2015). Therefore, women's empowerment makes a central contribution not only to improved household income and local economies but also shapes gender relations at the individual, societal and environmental levels (Sraboni *et al.*, 2014). Nevertheless, the disempowerment in economic, political, and social aspects of life mainly in agriculture constrains their

capacity to improve family livelihoods (Sharaunga, 2015). According to an IFPRI study, Rwanda has one of the highest overall WEAI scores at 0.91. The country records a gender development index (GDI) of 0.96, and about 73 percent of women indicate that they have achieved gender parity (Malapit *et al.*, 2014). Yet, the contribution of indicators of women's empowerment to SWC strategies has not been addressed in the context of Northern Rwanda.

The objective of the study is to assess the effects of women's empowerment indicators on SWC strategies. The novelty of this study is the application of the pro-WEAI in the ISURE model to measure empowerment, agency, and inclusion of women for SWC strategies. The study findings are relevant for designing SWC strategies and gender transformative approaches linked to different empowerment pathways. Production decisions need optimisation strategies for SWC that contribute to the feminisation of labor and natural resource use and management. Increased relative decision-making power regarding productive and financial resources would lead to the reallocation of household resources and their use by women. Participation of women in group membership constitutes an empowerment pathway, through social capital and collective action, to agricultural transition. Promoting labour-saving strategies for reducing the domestic workload and freeing up women's time to perform unpaid care work increases their decision-making authority over labor time (workload) and is a pathway to the labor market and other development opportunities.

The remainder of this paper is structured as follows. Section 5.2 discusses materials and methods, which include study area, design, data and definition of variables, analytical framework and model specification. Section 5.2 presents the results. The final section (5.3) discusses the findings, conclusions and policy implications.

5.2. Methodology

The study area, study design and data collection techniques are described in section 3.2.1 of chapter three.

5.2.1. Data and Definition of Variables

Based on labor time allocated to household chores and farm activities, the study identified five distinct SWC strategies. The strategies have been also defined with reference to gender roles and intra-household decision-making at household level. Table 5.2 shows all the strategies expressed as the number of hours allocated to each activity of SWC by each household decision-maker.

These strategies include invisible SWC (ISWC), soil and conservation (SC), soil fertility management (SFM), integrated soil management and water conservation (ISM and WC) and financing investment in SWC (FISWC). The ISWC strategy involves time and energy in supporting human well-being, arising out of social or contractual obligations. Household unpaid care works are invisible and are often undervalued or disregarded in economic analysis, public policy and this often causes underinvestment (Maestre & Horpe, 2016). It includes direct care of people, such as child care or care of dependent adults such as cooking, cleaning and collecting water or firewood. SWC strategies involve a combination of multiple practices that guide the protection, conservation and management of soil and water resources or the environment (Ahuchaogu *et al.*, 2022). Thus, an SFM strategy combines various practices in a farming system aimed at improving soil fertility (Birnholz *et al.*, 2018). ISM and WC integrate practices of SWC and SFM with knowledge and household decisions on how to adapt the practices to local conditions (Bekunda et *al.*, 2022).

The SC strategy involves the use of various practices (physical, agronomic or management measures) aimed to prevent and mitigate; to rehabilitate and restore degraded soils; and to conserve or safely drain soil water (Aryal *et al.*, 2018). The SFM strategy involves farming practices related to soil fertility in the farms owned by a household (Adimassu *et al.*, 2012). Investment in SFM can increase mineral efficiency and improve crop productivity (Kagabo *et al.*, 2013). The ISM&WC strategy forms a set of sustainable land management practices that involve the combined use of physical structures, fertilisers, organic inputs, and improved germplasm based on farmers' knowledge of local conditions and household decisions (Vanlauwe *et al.*, 2010).

The FISWC strategy involves financial investment in SWC strategies by any household member who migrated from primary production to off-farm employment. This variable consists of paying hired labor for activities since household members work outside the farm (non-farm employment). It was expressed as the amount Rwandan francs (RWF) spent on SWC investment using any of the SC strategy, SFM strategy and ISM and WC strategy or their combinations. This variable was converted into the number of hours spent on paid labor to finance investment in SWC.

Table 5. 2. Definition of variables used in the model

Variables	Definition
Dependent variables	
Invisible SWC investment (ISWCI) strategy	Number (log) of labor hours allocated to unpaid care work as invisible SWC investment.
Soil Conservation (SC) strategy	Number (log) of labor hours spent for activities related to physical land conservation as SC strategies only.
Soil fertility management (SFM) strategy	Number (log) of labor hours spent for activities related to SFM strategies only
Integrated soil management and water conservation (ISM&WC) strategy	Number (log) of labor hours household members on integrated soil management and water conservation
Financing SWC investments (FISWCI) strategy	Number of labor hours spent on paid labor to finance investment in SWC.
Independent variables	
Autonomy in income	If each male and female have a RAI above 1 (adequate if RAI>1) in AT LEAST one domain/linked to income from production.
Input in productive decisions	No of agricultural domains (adequate if there is AT LEAST TWO domains) in which a woman has some input in decisions or makes decisions.
Access to and decisions on financial services	Number of credit-related decisions in which the each participates in; and has access, solely or jointly, to a financial account (Adequate in AT LEAST ONE source of credit AND has at least one source of credit).
Control over use of income	Number of income decisions in which the both males and females participates (adequate if there is AT LEAST ONE income decision or can make decisions regarding wage, employment and minor household expenditure).
Work balance (Workload)	Number of hours spent doing primary & some secondary activities (adequate if each male and female worked less than or equal to 10.5 hours and not adequate if worked more than 10.5 hours)

Group membership	Number of formal and informal groups to which both each belongs to (adequate in at least one group).
Membership in influential groups	Number of groups that both male and female participate in which can influence the community (adequate if active member of at least ONE).
Age	Average age of the HH head (in years)
Education level	Mean years of formal education (Primary one =1 to university=15).
Main occupation	Equals 1 if off-farm is primary occupation, 0 otherwise)
Input-market	Walking distance to the nearest input market (Minutes)
Output-market	Walking distance to the nearest output market (Minutes)
Plot distance	Average walking distance from home to plot (in Minutes)

Independent variables used in the model include eight indicators of pro-WEAI, socio-economic characteristics and institutional factors. The effect of intrinsic agency (measures the power within) on SWC strategies was captured using the relative autonomy index that measures woman's autonomy in income. It shows the motivations behind the actions of a woman with respect to household income by distinguishing internal and external forms of regulation (Yount *et al.*, 2019). In line with this index, the intrinsic agency was operationalized as comprising one indicator related to autonomy in income. The effect of instrumental agency (the power to) on SWC strategies comprised mainly of decision-making questions that span many different aspects (production, assets, credits and loans) to demonstrate women's influence in family decision (Malapit *et al.*, 2019). The agency uses items that capture a woman's decisions about household earnings (including her husband's), household purchases (large and daily), seeking medical treatment, and visits to family and friends. The collective agency (power with) was measured through group membership and membership in influential groups to capture respondents' engagement in community activities and shared goals with other women in the same community.

5.2.2. Analytical Framework and Model Specification

The study defined five dependent variables for defining levels of labor time investment in SWC strategies. The study assumed that the labor time devoted to each SWC strategy is mutually exclusive as they are unrelated. This means that a household member cannot allocate labor to more than one SWC strategy at the same time. The present study expressed labor time allocated to each SWC strategy in terms of the number of hours the

household decision-maker spent on activities related to investing in the aforementioned SWC strategies.

For each SWC strategy, a separate equation was specified with the relative information included in each equation. To select an appropriate model for estimation, different methods for testing model specification including autocorrelation and other forms of misspecification were applied. Given the system of equations, the study adopted Zellner's seemingly unrelated regressions Equations (ISURE). The appropriate use of ISURE at the expense of ordinary SURE or ordinary least squares (OLS) estimation is explained by the fact that the sample represents only household members who invested time and finances in different SWC strategies (Faniyi *et al.*, 2018). The model is a type of limited dependent variable (LDV) which depicts a corner solution case with a mass of zeros, and non-zero values (continuous time amount of SWC strategies) that are true observations of the dependent variable (Amore and Murtinu, 2019). Further, the ISURE model provides parameter estimates that converge to unique maximum likelihood parameter estimates. The benefit of Zellner's ISURE model is that the SURE estimators utilize the information present in the cross regression (equations) error correlation and hence it is more efficient than other estimations such as OLS and ISURE tobit models (Khalik Salman *et al.*, 2010). As argued by Huang (2001), the SURE tobit model can be regarded as a reduced form of a simultaneous equation tobit, which is a generalization of a single Tobit regression model. With the SURE tobit model, suppose there are p regressions with n observations in the system. The observed variable y_{ij} is determined by:

$$Y_i = X_i\beta_i + \varepsilon_i \qquad \text{with } i = 1,2,\ldots\ldots M \tag{5.1}$$

Where Y_i is a (T x 1) vector of dependent variables, ε_i is a (Tx1) vector of random errors with E(ε_i) = 0, X_i is a (T X n_i) matrix of observations on n_i exogenous dependent variables including a constant term, β_i is an (n_i x 1) dimensional vector of coefficients to be estimated, M is the number of equations in the system, T is the number of observations per equation, and n_i is the number of rows in the vector β_i.

The m system of equation can be separately defined by the following equation:

$$Y_1 = X_1\beta_1 + \varepsilon_1 \tag{5.2}$$

$$Y_2 = X_2\beta_2 + \varepsilon_2$$

$$Y_m = X_m\beta_m + \varepsilon_m$$

This econometric estimation involves the estimation of the effect of pro-WEAI indicators on SWC strategies. The ISURE model for the proposed SWC strategies matrix is set up as a system of linear regressions written in matrix format:

$$\begin{matrix} y_1 \\ y_2 \\ . \\ . \\ y_5 \end{matrix} = \begin{bmatrix} x_1' & 0 & . & . & 0 \\ 0 & x_2' & . & . & 0 \\ . & . & . & . & . . \\ . & . & . & . & . \\ 0 & 0 & . & . & x_5' \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ . \\ . \\ \beta_5 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ . \\ . \\ \varepsilon_5 \end{bmatrix}$$

(5.3)

This model can be written compactly as :

$$Y = X\beta + \varepsilon$$

(5.4)

where Y and ε are of dimension (TM x 1), X is of dimension (TM x n), $n = \sum_{i=1}^{M} n_i$, and β is of dimension (TM x n). Note that the dependent variables Y_i are the natural logarithms of the number of hours spent on each SWC investment strategy over the two agricultural seasons. Therefore, our econometric estimation of ISURE will be shown in the equation.

$$y_i = y_i + y_i WEAI\ indicators + y_i Socioeconomics + y_i Institutional\ factors + \varepsilon_i$$

(5.5)

The matrix X_i is the vector of pro-WEAI indicators, socio-economics and institutional factors assumed to affect SWC investment strategies.

For analysis, we employed an independent t-test and ISURE. Women's empowerment was expressed in terms of adequacy in each of the indicators of pro-WEAI (Diiro *et al.*, 2018). The study obtained an aggregate empowerment score of 0.815 (i.e. 81.5%). In line with Alkire *et al.*, (2013), a woman achieves empowerment if she has adequacy in at least 80% of the weighted indicators. The independent t-test was used to determine whether there was a statistically significant difference between male and female beneficiaries. ISURE models appear to be joint estimates from several regression models, each with its own error term. The regressions are related because the (contemporaneous) errors associated with the dependent variables may be correlated (Cameron & Trivedi, 2010). When fitting the models, a comparison was made between independent variables from ISURE results (in terms of coefficients and standard errors) and ordinary least squares (OLS).

We performed the "sureg" command in Stata 14.2 for the joint tests. We use the *small* and *dfk* options to obtain small-sample statistics comparable with OLS estimates (regress). OLS results are in appendix 4. In estimating the ISURE model, we have allowed error terms of the equations to be correlated and have estimated the full variance–covariance matrix of the coefficients. We performed the Breusch-Pagan test of independence to specify the correlation between error terms. We found that, for the SWC strategies, the correlation of the residuals was significantly different from zero, and therefore was no correlation between indicators and their covariates.

5.2.3. Test for Multicollinearity between WEAI Indicators and Covariates

The test for multicollinearity was conducted by using the regress command to fit a multiple linear regression model using each SWC strategy as the outcome variable and WEAI indicators and other covariates as the explanatory variables. Using the "**estat vif**" command in Stata, it was found that the two variables such as "autonomy in income and input in productive decisions" have severe multicollinearity. Similarly, the "corr" command show that the two variables were highly correlated (0.9). By dropping the variable "input in productive decisions" and re-run the vif, it was found that the variable "autonomy in income" has a moderate vif (less than 5). Similarly, other variables including control over use of income and work balance (workload)" had moderate vif. Thus, the multicollinearity is not severe enough to require attention. Most variables have a vif value close to 1 indicating that there is no collinearity between them.

5.3. Results and Discussion

5.3.1. Descriptive Statistics of Respondents' Characteristics

Results on socio-economic characteristics (Table 5.3) indicate that both males and females are middle-aged, implying that they can actively engage in agricultural production including activities related to investing in SWC strategies. However, female farmers were seven months older than male farmers. Young males migrate for off-farm employment leaving old females doing agricultural production. Females have attained 2.55 fewer years of education and lesser chances of occupational opportunities than their male counterparts. Low education level can limit women's involvement in decision-making regarding household and SWC activities.

Results on institutional factors reveal that both male and female farmers use a short distance to access markets for input and output. However, women use more time (between 3 to 16 hours) than men to reach input and output markets.

Table 5. 3. Descriptive statistics of male and female's characteristics

Variables	Female	Male	Mean difference
SWC strategies (Dependent)			
Invisible SWC investment (in 000hours)	1.76	1.54	0.22***
Soil conservation strategy (in 000hours)	3.62	9.18	2.71***
Soil fertility management strategy (in 000 hours)	6.96	24.39	-17.42***
Integrated soil management and water conservation strategy (in 000 hours)	14.45	28.66	-14.21***
Financing SWC strategy (in 000 hours)	0.409	0.657	-0.248**
Women's empowerment indicators			
1.Intrinsic agency			
Autonomy in income	0.16	0.22	-0.06 ***
2. Instrumental agency			
Input in productive decisions	2.42	2.256	0.16 ***
Access to and decisions on financial services	0.16	0.18	-0.02**
Control over use of income	1.63	1.56	1 .08***
Work balance (Workload)	771.19	758.11	13.081***
3. Collective agency			
Group membership	0.55	0.56	-0.01
Membership in influential groups	3.22	3.46	0.24***
Socio-economic factors			
Age	45.55	44.84	0.71**
Education level	2.55	5.10	-2.55 ***
Main occupation	0.20	0.39	-0.19 ***
Institutional Factors			
Input-market	26.98	23.20	3.78 ***
Output-market	32.83	25.76	7.07 ***
Plot distance	53.40	66.22	-12.82 ***

Significant codes: (***) at 0.01; (**) at 0.05; and (*) at 0.1 indicates the difference between means for male and female.

This is associated to their heavy workload in addition to reproductive roles that women perform, including childcare, are among the causes of the time difference between

males and females. Women use fewer hours than men to reach the plots from home since they tend to work to the nearest farm/plots. However, women use more traveling time than men and more hours on domestic and agricultural activities.

The mean time difference between males and females were significantly positive for ISWCI (221.04 hours) and SC practices than males (2709.01 hours) indicating that the female spend more time for these strategies than male. On the other hand, the mean time differences were negative for SFM strategies (-17423.46 hours), Integrated soil management and water conservation (-14,210 hours), and financing SWC investments (-248.51 hours), indicating that males spend more time than females. The differences in capabilities is one of the driving forces for observed high male investment in SWC compared to female investment (Faniyi *et al.*, 2018).

Results show that females' autonomy in income is low compared to men as explained by the negative mean difference. Results on instrumental agency show that females have a significantly higher number of agricultural domains in which they make productive decisions, a higher number of income decisions, and a better work balance than male farmers. Females control most of the income decisions from agricultural production implying that their roles and power position in agriculture are changing. Increased women participation decisions may explain a transitional process from staple to commercial farming in NTAEs.

Women spend more time (13.081 hours) on primary and some secondary activities. The heavy domestic workload is the cause of time poverty, which restricts opportunities for women in education, and training including meetings or earning income from farming and off-farm employment. When comparing domestic to market labor, the study finds that women have limited time relative to men (Bardasi & Wodon, 2010). Women's time constraint is a consequence of the disproportionate level of household tasks they are supposed to accomplish given the existing social structure (Turner & Grieco, 2000). Results also show that male farmers have more access to and decisions on financial services, assets, and credit-related decisions than female farmers.

5.3.2. Importance of SWC Investment on Agricultural Export Crops

Crop production and SWC investment are highly complementary because the conservation of soil, water and vegetation leads to higher productivity of crops and thus the improvement of livelihoods. Five SWC strategies linked with the production of NTAE crops (mainly Irish potatoes, maize, beans, cassava and coffee) are recognized (Figure 5.2).

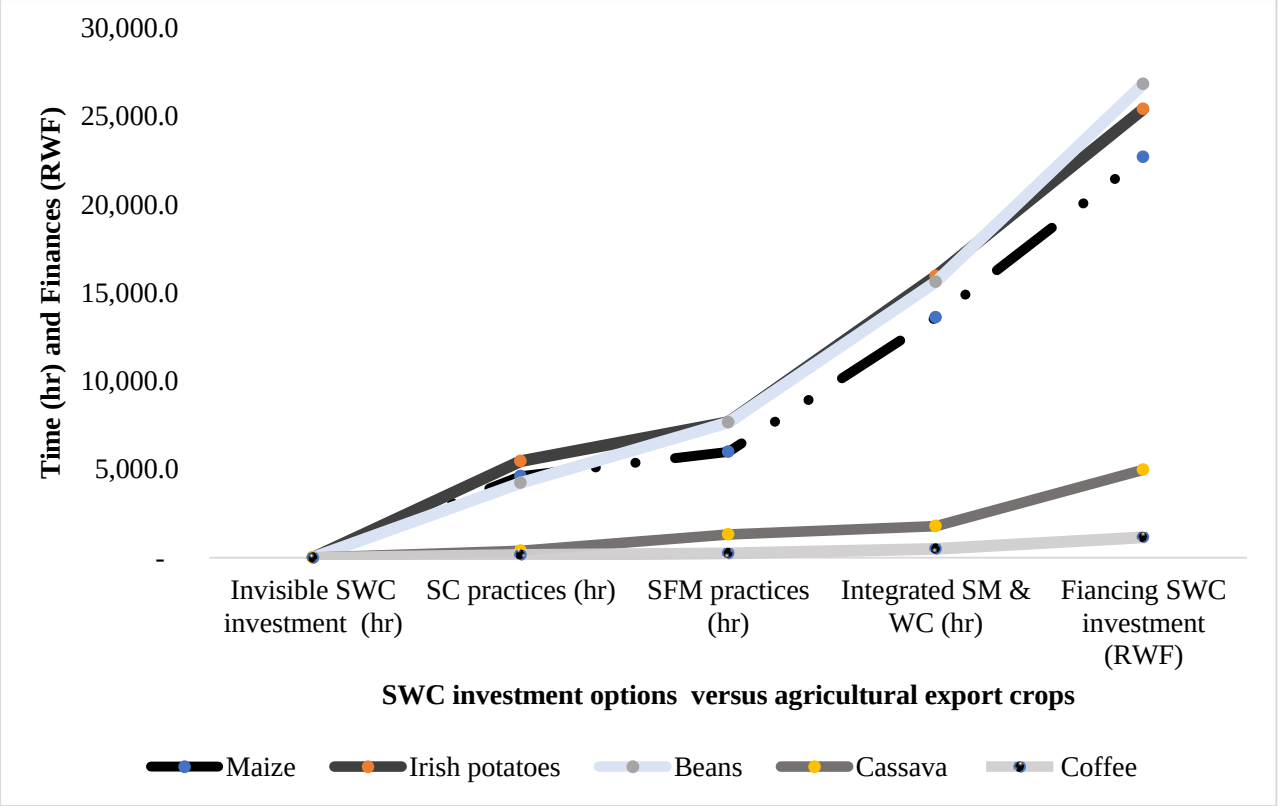

Figure 5. 1. SWC investment options in relation to NTAEs

Findings show that invisible investment in SWC by unpaid careworks had no substantial contribution to the production of NTAE crops. Women performing household chores and other unpaid work have remained invisible to both Neoclassical and Marxist analysis, and thus in their importance to invest in SWC for NTAEs crops (Aredo,1995). This category includes more females than males constituting the invisible labor force and thus their production and investment capacity is undervalued. Culture and norms limit people involved in invisible activities to those subsistence tasks and other SWC that can be performed around the homestead for which they receive no remuneration (Muriithi *et al.*, 2017).

The results show that there was little significance in investing in soil conservation (SC) strategies for the production of coffee and cassava. SC strategies are not suitable and cause considerable challenges for coffee and cassava production due to the base saturation and pH of volcanic soils characterizing this agro-ecological zone (Mukashema *et al.*, 2016). SC strategies were more important for the production of beans, maize and Irish potatoes. Farmers' perception on discounted benefits associated with improvement in crop production, reduction in lime requirement and total nitrogen content provide a motivation to invest in SWC practices (Addis *et al.*, 2020).

Investment in SFM strategies can increase mineral efficiency and improve crop productivity (Kagabo *et al.*, 2013). The significance of SFM in the production of coffee, cassava, beans and Irish potatoes was relatively high compared to that of SC practices. There was no difference in the importance between SC and SFM practices for the production of maize. SFM practices were more important for the production of maize, beans and Irish potatoes. The combined use of inorganic and organic fertilizers is an excellent optimization strategy for soil fertility management specifically in the volcanic soils (Meya *et al.*, 2020). ISM and WC strategies have a slightly high importance on the production of both Irish potatoes and beans. There is considerable importance of ISM and WC strategy for the production of all the crops. The importance of this integrated technology was found to be low for coffee and cassava, moderate for maize and high for beans and Irish potato production. The results indicate that the use of integrated technologies is very important to improve the productivity of NTAEs crops.

Small farm households invest in SWC to improve land productivity by regenerating vegetation, rehabilitating the soil and reducing sediment yield (Nyamekye *et al.*, 2018). Perceived production potentials, increase in profit, improvement of wellbeing and livelihood, and reduced workload are sources of incentives for smallholders to finance investment in SWC (Ndagijimana *et al.*, 2019). Findings reveal that the FISWC strategy was fairly important for maize production compared to Irish potatoes and beans. The importance of FISWC increased considerably for cassava and coffee production in comparison with other investment strategies. Small farm households opting to finance SWC could regard these crops as a component of livelihood strategies. This is because farmers tend to invest more in SWC when competitive markets for selling crops are available. Teshome *et al.* (2019) argued that improved access to markets, improved non-farm employment opportunities, and increased producer prices can increase household welfare, but reduces incentives to deploy labor to stimulate investment in SWC.

5.3.3. Results of ISURE Model on Women's Empowerment and SWC Investments

Econometrics results on the effect of women's empowerment indicators on SWC strategies using the ISURE model are shown in Table 5.4. The overall significance test of the ISURE model was done using the Breusch-Pagan (BP) statistic for cross-sectional independence in the residuals.

Table 5. 4. ISURE estimation of effect of women's empowerment on SWC investments

	Variables	Invisible SWC	SC strategies	SFM strategies	Integrated SM & WC	Financing SWC
Intrinsic agency	Autonomy in income	-0.26	-1.51 ***	1.23**	5.68***	0.19
		(0.89)	(0.46)	(0.55)	(1.27)	(0.44)
Instrumental agency	Asset disposal and acquisition	-0.31*	0.10	0.06	0.01	-0.15
		(0.19)	(0.13)	(0.14)	(0.17)	(0.11)
		-1.24***	-0.15	0.51***	0.27**	-0.11
	Access to and decisions on financial services	(0.24)	(0.12)	(0.16)	(0.12)	(0.10)
	Control over use of income	0.26	-0.24	0.28	0.14	-0.05
		(0.24)	(0.18)	(0.23)	(0.24)	(0.17)
	Work balance (Workload)	0.0012*	0.0003	-0.001 ***	0.001*	0.001**
		(0.003)	(0.0004)	(0.0003)	(0.0005)	(0.0003)
Collective agency	Group membership	0.03	0.45 ***	-0.32 ***	0.22*	0.09
		(0.13)	(0.10)	(0.11)	(0.12)	(0.08)
	Speaking in public	0.14 **	-0.08***	0.06***	-0.08**	-0.02
		(0.05)	(0.02)	(0.02)	(0.03)	(0.02)
Socio-economic factors	Age of the gender of household	-0.01*	0.01***	-0.01 ***	0.04***	0.03***
		(0.01)	(0.004)	(0.004)	(0.01)	(0.003)
		0.06 ***	0.05***	-0.04***	0.06***	0.09***
	Education of the gender of household	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
	Occupation of the gender	-0.13	0.00	0.48***	-0.14	-0.17

		(0.16)	(0.11)	(0.13)	(0.13)	(0.10)
Institutional	Access to input-market	0.01**	0.003	0.001	-0.005 *	-0.002
factors		(.003)	(0.002)	(0.002)	(0.003)	(0.0019)
	Access to output-market	-0.01***	-0.0005	0.003	-0.003 *	-0.01***
		(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
		0.01***	0.01 ***	0.003***	0.01***	0.01***
	Distance plot-home	(0.0011)	(0.002)	(0.0009)	(0.001)	(0.002)
		-2.91 ***	-0.74	2.42***	-2.87 ***	-3.82***
	_cons	(0.67)	(0.48)	(0.42)	(0.62)	(0.40)
	Log likelihood	-225.26	-433.29	-429.33	-324.47	-713.97
	Number of observations	803	1,419	1,180	1,041	1,464
	Breusch-Pagan test of independence	129.34	141.21	107.70	150.27	394.19
	Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000

[1]Significant codes: (***) at 0.01; (**) at 0.05; and (*) at 0.1 for indicators and other variables . [2]Standard Errors are shown in brackets

The BP cross-equation constraints test the correlation between error terms in the two equations or test of independence. The resulting chi2 between the first two equations was statistically significant (chi2 of 23.952 and Pr of 0.0000). The chi2 (29.738) and Pr (0.0000) between the third and fourth equations implies that there is no correlation across equations. The model results are interpreted as a percentage change in the dependent variable Y as a result of a one-unit change in independent variables. For instance, a one-unit increase in women's autonomy will result in 57% and 12.3% labor hours of investing in Integrated SM & WC and SFM strategies respectively. Contrarily, it will reduce the labor time used for investment in SC practices by 15%. In addition, a unit increase in women's access to and decisions on financial services leads to a 51% and 27% increase in the labor time for investing in SFM strategies and Integrated SM and WC respectively but reduces invisible SWC by 12.4%.

Results show that women's intrinsic agency in terms of autonomy in income was positively associated with time investment in SFM and integrated SM and WC strategies, but negatively associated with investment in SC strategies.Autonomy is the ability to obtain information and make decisions (Acharya *et al.*, 2010). An autonomy indicator can facilitate access to productive resources (food, land and income), and social resources (knowledge, and prestige within the community). This is important in reducing gender productivity differences as well as gaps in participation and labor provision for the production of NTAEs. Okonya *et al.* (2019) argued that in the production of NTAEs, a large proportion of household decisions are made jointly.

The study found significant effects of instrumental agency on SWC strategies with regard to increased women's asset disposal and acquisition, access to and decisions on financial services, and work balance. Women's participation in SC strategies could be linked to their involvement in staple food production and subsistence farming as compared to men and thus they are more responsible for food crop production activities. Negative effects of both SFM and ISM & WC strategies could reveal that NTAEs are male-dominated cash crops so that men are in charge of decisions regarding production and improved farm management practices. Enhancing women's access to production decisions and use of productive resources leads to economic benefits from increased agricultural productivity (Emmanuel *et al.*, 2016).

Women's asset disposal and acquisition have a negative relationship with invisible SWC. Results show that women's level of involvement in unpaid household work is decreasing with more focus on farm management activities and production of NTAEs crop,

and non-farm employment. Due to higher returns to labor in non-farm activities, households attempt to divert labor from agricultural activities to non-farm activities. This is because improved non-farm employment opportunities increase household welfare but reduces households' incentives to deploy labor for investing in SWC, leading to higher levels of soil erosion and rapid land degradation (Singh & Pattanaik, 2020).

Women's increased access to and decisions on financial services positively contribute to labor time invested in SFM and integrated SM & WC strategies, and negatively to strategies related to invisible SWC and SC. The negative association with invisible SWC implies that rural women are changing roles from underinvestment and thus freeing up time to perform farm and other productive tasks. When a woman works outside, she can contribute to the family income, which has a great impact on improving livelihoods (Mohiuddin *et al.*, 2020). Results on negative association with investment SC practices signal that women's great involvement in farm activities related to NTAEs calls for improving their access to agricultural assets. Results show that the number of credit-related decisions in which a woman participates could lead to higher diversity in terms of agricultural production and food consumption (Sariyev *et al.*, 2020). Greater women's access reduces gender asset gaps which increases women's participation in household decision-making regarding farm and non-farm operations. This suggests that closing gender gaps is believed to be achieved if female managers are endowed with assets and if structural disadvantages in land size and quality labor inputs are addressed. The findings corroborate the recommendation by Anderson *et al.* (2021) that increasing women's decision-making authority over their own labor would increase their participation in profitable farm investment and non-farm labor markets.

Results show that the number of hours a woman spent on workload increases labor time allocated to the invisible SWC. Women's burden for domestic work was associated with less agricultural resources and low decision-making power. Increasing women's decision-making authority over their own labor time and mobility would increase their participation in markets, including off-farm labor markets (Mohiuddin *et al.*, 2020). Results also reveal that women's increased work balance has a small but positive contribution to labor time allocated to integrated SM and WC and Financing SWC strategies and less participation in SFM strategies. This reveals women's unprecedented changes in agricultural household labor between food crop production and production of NTAE crops using integrated soil fertility management practices and hired labor. Following Haggblade *et al.* (2010) this is an

indication of agricultural transition aimed at moving from primary agricultural production to non-farm labor market participation.

Results on women collective agency show that Group membership was negatively associated with time allocated to SFM strategies and positively linked with labor time investment in integrated SM and WC and SC strategies, mainly because women self-help groups facilitate access to information and increased women power. Results also imply that social capital and participation in collective action influence women's efforts for improving SWC. Thus, women's lack of participation in social groups including saving and lending activities in their community may lead to disempowerment. Expansion of women's social networks through community groups would lead to greater empowerment and movement from subsistence farming to non-farm employment or investment (Kabeer, 2017). Access to financial decision-making by a female is crucial for agricultural investment. Farming groups improve access to agricultural resources and shift to better farming methods (Othman *et al.*, 2020). For example, Kabeer (2017) argued that membership in microfinance groups has a role to play in economic pathways through the enhancement of women's economic contributions to the family.

Results show a significant variation in socioeconomic characteristics (age, education, and occupation) and institutional factors (market access, proximity to town and plot distance). Labor timer investment in SC, integrated SM and WC and financial SWC strategies increases with the age of female farmers, and reduces invisible SWC and SFM strategies, reflecting the importance of farm experience and extension education. Age reflects women's duration and experience in farming activities. More off-farm occupational opportunities in the household increase the chances for investing in all SWC investment strategies. Results further highlight that an increase in years of education is increasingly associated with labor time investment in SC, integrated SM and WC and financing SWC strategies, but negatively associated with SFM strategies. Lecoutere and Jassogne (2019) suggested financial extension efforts aimed at addressing intra-household information asymmetries as one of the best means of empowering women. However, a low level of education causes an increase in domestic unpaid activities and reduces the intensity of SC practices. Limited access to education for women compared to men could be attributed to women's heavy dependence on crop production for livelihoods. Similar findings indicate that gender differences in education may reflect differences in human capital and, hence, could indicate women's relative bargaining position in the household (Diiro *et al.*, 2018). According to Anderson *et al.* (2021), most of

the uneducated women that participate in off-farm occupations are generally in self-employment and activities with lower returns.

Occupation opportunities in off-farm employment cause an increase in labor time devoted to SFM strategies. Women's contribution to household income is increasing through their participation in non-farm activities and NTAEs production. Participation in non-farm activities entails household labor re-allocation which may have implications on farm labor (Neog & Sahoo, 2020). The income from off-farm sources can be used to pay for hired labor, and to invest in soil fertility management for the production of NTAE crops (Su *et al.*, 206).

Institution factors such as access to markets for input and output, and distance plot-home have mixed effects on the intensity of investing in SWC. These results could be associated with high prices of agricultural inputs that may discourage farmers, mainly female-headed households to participate in farm production and fertility management of NTAEs but also create more chances for unpaid domestic work. The presence of local market imperfections limits women from realizing gains from commercialization (Güneri & Durmuş, 2020). Distance from home to plot positively the intensity of investing in most soil and water investment strategies. A shorter distance from the home to the plot can always motivate farm investment. Women's lack of access to institutions and markets is a key barrier to technology adoption and agricultural productivity (Ragasa, 2012). The results are consistent with (Wiggins, 2018) that households with agricultural resources, land and assets have the advantage of investment and employment opportunities for female farmers.

5.4. Conclusion and Policy Implications

The study adopted the pro-WEAI and ISURE model to assess the effect of indicators of women's empowerment on five SWC strategies. The study found that women's empowerment indicators have mixed effects on all SWC strategies. This implies that, as women become increasingly empowered in decision-making, sustainable intensification can be achieved by harnessing the positive aspects of adopting SWC strategies. Consistent with this, female farmers would focus on SWC strategies that improve farm productivity, regenerate vegetation, and rehabilitate degraded soils. The findings reveal that, although women's empowerment indicators have no significant effects on financing SWC, both financing SWC and integrated SM and WC strategies can provide more economic benefits and fewer opportunity costs compared to the rest of the SWC strategies, indicating that they exhibit more comparative advantage in producing high-value crops. The findings suggest interventions that link farmers to improved markets, producer prices, and non-farm

employment opportunities to motivate their time and financial investment in SWC strategies that have high returns.

The study found that women's empowerment through instrumental agent could be explained by the increasing role of women in land management and erosion control as a pathway to the feminisation of natural resource use and management due to women's role in land management and SWC investment. The study also found that financial and social resource indicators influence the commercial production of NTAEs through participation in both profitable farm investment and non-farm labor markets. However, women are reluctant to shift to commercial production, implying that men still dominate decisions regarding the production of high-value crops. Nevertheless, women's employment in farming has become a means to their empowerment, as female participation in agriculture has become a means to agricultural transformation and poverty reduction.

The study recommends that developing economic strategies (related to production decisions and financial services) and gender transformational approaches (such as group membership and labor-saving technologies) by developing necessary skills and know-how that encourage women's investment in SWC should be pursued as a pathway to agricultural feminisation. Hence, policies aimed at increasing women's propensity to respond to employment opportunities in commercial agriculture and decision-making authority over farm and non-farm operations would reduce gender asset gaps. The move would help them to contribute to the family income and improve their livelihood.

The study also found that women's empowerment through the collective agency that entails group membership and influence in the community explains the role of WE indicators through social capital and collective action in promoting soil conservation and integrated management of the soil. Since group membership can improve access to agricultural resources and information and therefore cause a shift to better farming methods, strategies to expand women's social networks is a pathway to greater economic empowerment. Finally, the study found that socio-economic and institutional factors such as access to institutions and markets contribute to increased investment in SWC strategies. Promoting extension education and infrastructural services would probably reduce intra-household information asymmetries for women farmers and increase investment in SWC strategies. Further, policies that promote market participation and focus on making markets more accessible to female farmers, are encouraged.

CHAPTER SIX

IMPACT OF SOIL AND WATER CONSERVATION INVESTMENT ON FARM HOUSEHOLD INCOME IN RWANDA VOLCANO REGION: AN INSTRUMENTAL VARIABLE QUANTILE APPROACH

Abstract

Soil and water conservation technologies and practices contribute to sustainable agriculture and rural poverty reduction. Yet, the relationship between farm household income and SWC investment in Rwanda is not well understood. The aim of the study is to assess the effects of investing in SWC on household income and to understand how various classes of smallholders can benefit from such an investment. The study used survey data collected from 422 farming households in Burera, Gakenke and Musanze Districts in Northern Rwanda. Descriptive analysis was employed to determine levels of use of SWC and soil fertility measures. Quantile estimation was used to classify farming households into three categories: the poor, middle-income earners and rich. The instrumental variable quantile regression was adopted to assess heterogeneous effects of financing SWC investment. The results revealed that the use of SWC and soil fertility measures is generally low. Agricultural income and off-farm casual wages were the largest income shares of the poor and middle-income earners. Financing investment in SWC increases income significantly for middle-income earners five times more than the poor, but it was not effective for the rich. Socio-economic factors and commercial crops had significant effect on income across the classes. Institutional factors have no significant effect for the poor and middle-income earners. The findings suggest that incorporating pro-poor interventions in SWC investment would increase the productivity and commercialization of cash and staple crops. These results inform a need to promote linkages between SWC investment and income diversification strategies to increase asset-building for the poor and close income gaps among the three farming classes. This suggests the need to introduce saving and lending innovations that link farm activities to non-farm opportunities.

6.1. Introduction

SWC technologies and practices contribute to sustainable agriculture and rural poverty reduction for smallholder households. Empirical studies prove that productivity gains from SWC can be associated with increase in household income and changes in food prices (Huang *et al.,* 2019). On-farm adoption of SWC have linked farm investment with employment generation and improvements in household welfare (Nyanga *et al.,* 2016).

Barriers to technology adoption, initial asset endowments and market access inhibit the ability of the poor to invest in SWC. Also, the effects of land and environment degradation are mostly perceived among socio-economically poor farmers (Thiry *et al.*, 2018; Thorn *et al.*, 2016).

The benefits and impacts of SWC are linked with development in human capital and agricultural commercialization. Thus, commercialization of agriculture could be geared towards financing investment in SWC (Chaudry & Wimer, 2016). SWC investment can in turn support commercialization and sustainable agricultural development (Ochieng *et al.*, 2017).

Economic effects of SWC have been empirically studied using both market and non-market approach and focused on farm practices that increase crop yield (Adgo *et al.*, 2013). Otherstudies that concentrated on the effects of commercialization on income and poverty (Ogutu & Qaim, 2019) and fiscal policies (Giorgia *et al.*, 2013) concluded that increase in household incomes leads to greater effect on SWC investment. SWC investment entails allocation of finances, time and labor in a farm for activities related to conservation of soil and water resources and improving soil fertility for future use. SWC measures (terraces, AEC ditches, agroforestry, hedgerows and waterways) contribute to stabilizing slope profile, control soil erosion and surface runoff and rehabilitate degraded land (Baba *et al.*, 2017). SF measures (NPK, DAP, Urea, Organic manure and pesticides) help to improve soil organic matter and nitrogen content as degraded by erosion (Mosissa *et al.*, 2019).

In Rwanda, farm-level investment is one of the principal sources of income of about 80% of households in the surroundings of the VNP. However, smallholders possess small lands ranging between 0.1 and 0.5 Ha (Bigler *et al.*, 2017). In addition, soil degradation due to heavy water erosion and persistent poverty hinders the development of farm-level investment. Low adoption of SWC measures has accelerated the rate of erosion and water quality deterioration, which makes farmers in the area incur heavy investment costs (Musafili *et al.*, 2019). To reduce the effects of erosion and promote investment in SWC and so SF measures, the country introduced a nationwide crop intensification program (CIP). Under this, the land husbandry, water harvesting, and hillside irrigation (LWH) project aimed for sustainable agricultural production by increasing access to input at 50% subsidy and household income while improving food and nutrition security (Mugonola *et al.*, 2013).

There is lack of empirical evidence backing the relationship between household income and SWC investment among smallholders in Rwanda. From a rural development

standpoint, it is critical to understand how various categories of smallholders can benefit from financing SWC investment at farm-level. It is also crucial to understand the linkage between agricultural commercialization, agricultural communication and extension services and SWC investment. Commercialization provides information that links complementary investment in farm and non-farm activities, market participation and household asset ownership. Access to agricultural extension and communication services (AAECS) involves farmers' participation and social learning to enhance mindset change for technology uptake in SWC.

This paper contributes to literature that links household income with SWC investment and provides evidence on important variables that are essential to the design of pro-poor interventions and policies that would close income gaps among categories of smallholder farmers. It also contributes to the methodology of impact heterogeneity using instrumental variable quantile regression (IVQR) and cross-sectional data, which is opposed to previous studies that used standard quantile regression. The effects of SWC investments are expected to be highly correlated with income and potentially endogenous justifying the use of IVQR approach to account for the heterogeneous effects and proper identification of causal effects.

The remainder of this paper is structured as follows. Section 6.2 provides details on materials and methods which include: the study area; study design, sampling and data; and description and measurement of variables. Section 6.3 describes the econometric model of IVQR. Section 6.4 focuses on descriptive analysis and empirical findings. Section 6.5 concludes and provides policy implications.

6.2. Methodology

The description of the study area and research design, sampling and data are described in section 3.2.1 of chapter three.

6.2.1. Description and Measurement of Variables

While there are various ways to measure income at household level, this paper estimated "household income was expressed in US Dollar (USD) by aggregating all receipts (monetary or in kind) by individual household members during a period of 12 months. At the time of survey, one USD was equivalent to 950RWF. Household income represents three types of financing investment based on three categories: the poor, middle-income and the rich. The poor do not invest due to very small farm sizes but earn farm wages. Middle-income earners are self-employed households, and are able to finance SWC investment to increase the productivity of their farms. The rich category includes farming households which decide to pay for investment in SWC but also earn a lot from off-farm employment. The survey questionnaire comprised information related to income each household member

received from different sources: agriculture farming (income from crop farming), livestock raising (income from selling livestock and livestock products), off-farm opportunities, renting houses and assets, remittances, and interests and dividends.

The total household income, obtained by summing up different income sources, was used to estimate quantiles and the distribution of three categories of farming households with reference to the firth household integrated living conditions (EICV5) in Rwanda appearing in Table 2.5 of section 2.5. The resulting income quantile estimation was consistent with the one provided by Jami (2018) into: the poor, middle-income earners and the rich.The EICV5 classification is based on annual consumption values developed for sampled households, where consumption was used as a proxy for income. Under the EICV5, the five consumption quintiles were further grouped into the three quantiles by combining similar categories of farmers into the poor (Q1 & 2), middle (Q3), and rich households (Q4&5). The resulting categories represent income quantiles at 25^{th}, 75^{th}, and 95^{th} percentiles respectively (NISR, 2018). According to EICV5, poor category of farming households (which combines the poor and extreme-poor households) is equivalent to 42.3% of the population who are below the poverty line, from which 17.4% are in extreme poverty (NISR, 2018).

Table 6.1 shows the measurement of dependent and independent variables: control variables or covariates used in the analysis. It was hypothesized that socio-economic and demographics factors (age, family size, educational levels, off-farm work, assets and livestock ownership) motivate household members decisions and adoption behavior to finance SWC investment (Teshome *et al.*, 2016). households. Financing SWC investment consists of paying hired labor for overall SWC investment activities because household members work outside the farm. It exhibits high economic benefits-that links farm investment with non-farm income.

Descriptive statistics of the dependent and independent variables are highlighted in Appendix 3. One of the limitations was related to the measurement of total household income due to issues of recall and reluctance of farmers to divulge information which could lead to fraught measurement and biased estimates. To address this issue, Jami (2018) suggested that collected data should not be correlated between the responses with farmers' observed characteristics (Jami, 2018).

Education was provided in years of schooling. It was assumed that more educated farmers possess much interest in investing in SWC measures due to awareness and knowledge on expected benefits of farm investment. Household size was defined as the

number of family labor. It was hypothesized that household size had a positive effect due to improved livelihood and job opportunities (Martin & Lorenzen, 2016).

Table 6. 1. Description and measurement of variables used in the study

Variables	Variable description
Dependent variable	
HH_INCOME	Average annual household income (USD) by all members in a household
Endogenous variable	
SWC_FINVEST	Is 1 if the HH pays labor to finance SWC, 0 otherwise
Socio-economic characteristics	
Gender	Gender of respondents (Female=0 & Male=1)
Age	Average age of the HH head (in years)
Household size	Average family size (numbers)
Education (years)	Years of formal education (Primary one =1 to university=15)
Off-farm employment	Off-farm employment (No=0 &yes=1)
Ownership of HH asset (log)	Household asset index (HAI)
Livestock ownership	Number of livestock owned by the HH (in TLU)
Institutional factors	
Access to agric-extension and communication services (AAECS)	From 1=Limited, 2= medium & 3=Diverse AAECS
SWC Program	If HH received SWC Program (No=0; Yes=1)
Gender program (GPI)	If HH received gender program (No=0; Yes=1)
Access to Input market (IM)	Walking distance to nearest input market (Mn)
Access to output market (OM)	Walking distance to nearest output market (Mn)
Proximity to town (PT)	Proximity to town (walking minutes)
Road status (%RS)	From 1=Very bad PT to 5= Very good
Plot characteristics	
Number of plots	Number of plots cultivated by the household
Plot distance	Average walking distance home-plot (Mn)
Farm size	Average cultivated farm size (Ha)
Plot location	1= Hillside, 2=Top of the hill 3=Valley

Crop commercialization	
Maize	Maize commercial production (No=0; Yes=1)
Irish potato	Potatoes commercial production (No=0; Yes=1)
Beans	Beans commercial production (No=0; Yes=1)
Cassava	Cassava commercial production (No=0; Yes=1)
Coffee	Coffee commercial production (No=0; Yes=1)

Following Njuki *et al.* (2011), asset ownership was calculated based on household domestic assets index (HAI). HAI was included as a proxy measure for the economic wellbeing of a household. The survey comprised a variability of questions regarding ownership of all movable assets (households, land, and other farm input and equipment) excluding livestock. The asset index was calculated by assigning a weight (w) for each of these assets and then adjusting for age. Livestock ownership was estimated with reference to conversion equivalents of SSA livestock into tropical livestock units (TLU). The survey questions indicated the number of animals for the different species kept by the households.

Institutional factors were measured based on walking distance to input and output markets, and proximity to town. It was hypothesized that a short distance to input and output markets would encourage member decisions to finance investment in SWC (Teshome *et al.*, 2016). Inclusive market access was explained by development of infrastructure, inputs costs, prices (output) as well as opportunity costs as average walking time. Access to Agricultural Extension and Communication Services (AAECS), such as extension, credit, and transport, was provided in three levels - limited, medium and diverse. AAECS are important for productivity enhancing interventions aimed at smallholder commercialization and cutting marketing margins. Following Aung *et al.* (2016), the calculated AAECS score (from 1 to 12) was classified into: limited AAECS (1-3), medium AAECS (4-5) and diverse AAECS (>6).

Other institutional factors related to project supported interventions and cash crops commercialization have a high propensity to stimulate financial investment. Farm sizes (measured in square meters), slope steepness, plot location, and distance of plot from homestead (in minutes of walking distance) were expected to induce changes in land management practices in the short term (Helena *et al.*, 2015). In fact, very steep slopes may discourage SWC investment due to expected low return on investment. The more remote the distance from home to plot, the lesser the investment in SWC due to increased transaction costs (Gebremedhin & Swinton, 2003).

6.2.2. Model of Instrumental Variable Quantile Regression

The economic effects of SWC have been widely determined using both market and non-market approaches with focus on farm practices that increase crop yield (Adgo *et al.*, 2013). This study introduced an IVQR approach to account for heterogenous effects and proper identification of causal effects. IVQR is motivated by the continuous nature of household income variable as different from the control functional (CF) approach adopted to dummy income dependent variable (Chernozhukov & Hansen, 2008). Also, inferential procedure of IVQR arises from an estimation algorithm. With its important feature of being robust to weak and partial identification, IVQR remains valid in cases where identification fails completely (Lee, 2007).

Using IVQR, the study assesses heterogeneous effects of SWC investments on total household income of three categories of farmers (the poor, middle-earners and the rich). IVQR is important to inform strategies that could reduce income gap for various classes of smallholder farmers as it is more efficient than two stage least squares used in previous studies (Verkaart *et al.*, 2017; Wooldridge, 2015). Also, The IVQR is chosen to account for endogeneity in case of large samples failure to do so may yield to biased estimates (Chernozhukov & Hansen, 2008).

Several studies employed probit and tobit models to measure income poverty or poverty incidence, gap and severity to respectively measure poverty incidence, and asses the joint influence of factors of poverty incidence, gap and severity. The headcount index (HI), as in equation 2.1, measures the proportion of the population with incomes less than the poverty line. Poverty gap index (PGI) to assess the extent to which households on average fall under the poverty line (in equation 6.1). Poverty severity index (in equation 2.3) takes into account both the distance separating the poor from the poverty line and inequalities among the poor.

$$P_H = 1/N \sum_{i=1}^{N} I\left(C_i \prec z\right) \tag{6.1}$$

$$G_i = \left(z - y_i\right) I\left(C_i \prec z\right) \text{or} \; P_H = 1/N \sum_{i=1}^{N} \left(G_i / z\right) \tag{6.2}$$

$$P_H = 1/N \sum_{i=|N}^{N} \left(G_i / z\right)^{\alpha} \; \left(\alpha \geq 0\right) \tag{6.3}$$

N is the total population where, *(z)* is the poverty line and *(Ci)* is income or consumption expenditure. If the bracketed expression is true, the index *I*(.) takes the value of one and zero otherwise.

In the majority of poverty studies, poverty estimates have been expressed using inequality indexes (Gini coefficient and Theil indexes), which can show poverty distribution.

However, these measures are harder to develop than income poverty indicators and cannot be computed for consumption, income, or other monetary variables. These indexes also vary when the distribution varies but are not concerned about the share of income that goes to different income groups such as the top, bottom, or the middle. Quantile regression models are suitable for assessing SWC investment effects since they enable the analysis of income or poverty determinants for households. However, the relative importance of each of the factors can vary depending on the degree suffered by each class of poor farmers. Studies in SSA have used quantile analysis to evaluate the impacts of agricultural commercialisation and remittances on income poverty and inequality, and rural-urban differences in poverty (Ogutu & Qaim, 2019).

6.2.3. Econometric Model of Instrumental Variable Quantile Regression

Instrumental Variable Quantile Regression was formulated based on a set of regressions as follows:

$$Y_i = D_\alpha(U) + X'\beta(U) \qquad \text{U ~U (0,1)} \qquad \text{given:….Z….and….X} \qquad (6.4)$$

where D is a binary vector which indicates the status of financing SWC investment (SWC_FINVEST). It is instrumented to the treatment group that pay labor to finance SWC investment. Y_i is the outcome as household income, X is a vector of covariates, Z is a dummy indicating assignment to treatment group. Z is a non-separable error given by $U|_{x,z}$~uniform (0,1) with z being a vector of excluded instruments.

In Equation 6.4, the source of endogeneity was explained by the coefficient of interest, β, which measured the impact of financing SWC investment on household income. However, SWC investment may be impacted by household income. Due to the correlation between D and U, SWC investment becomes potentially endogenous leading to biased estimates of β.

The indicator D is given by:

$$D = \delta(X, Z, Y) \qquad (6.5)$$

where $\delta(.)$ is an unknown function, Z, is a vector of instrumental variables such as distance plot to home, AAECS and plot location. X is a matrix of all the variables, V is a vector of unobserved variables and is statistically dependent on U

The IVQR estimator is assumed to be a linear model of the following form:

$$Y = q(SWC, X, \mu) = \alpha_\tau d + x\beta_\tau + \mu \qquad with \cdots d = SWC$$

(6.6)

The objective will be to estimate the treatment effects defined by

$$q(SWC, X, \mu) - q(SWC^0, X, \mu)$$

(6.7)

The endogeneity of SWC investment may originate from different factors such as unobserved heterogeneity, reverse causality, or measurement error (Ogutu & Qaim, 2019). Under certain assumptions, this endogeneity problem can be solved by the IV method. IVQR was applied to estimate between financing SWC investment against instruments (equation 3). The resulting estimates were incorporated in the standard quantile regression to obtain conditional income quantiles (equation 6.8).

The specification of the standard quantile regression and estimation of conditional quantiles for any choice of quantile $\tau \in (0-1)$ were based on Koenker and Basset (1978):

$$Y_i = \alpha(\tau)d_i + \beta_1(\tau)x_{1i} + \beta_2(\tau)x_{2i} + \ldots\ldots\ldots\ldots + \mu_i, \quad with \cdots i = 1,2,2\ldots\ldots\ldots\ldots, n \qquad (6.8)$$

By linearizing the standard quantile model (in equation 6.9) of household income variable, Y, conditional on a treatment variable, SWC, and a vector of control variables including the constant, x., the resulting equation:

$$HH\_INCOME_i = \alpha(\tau)SWC\_FINVEST_i + \beta_1(\tau)Socioecon_{1i} + \beta_2(\tau)Institutional_{2i} + \beta_3(\tau)Plot_{3i} + \beta_4(\tau)Cropcommercial_{4i} + \ldots\ldots\ldots + \mu_i \qquad (6.9)$$

The treatment variable SWC_FINVEST indicates if household pay labor to finance SWC investment, u represents non-separable error term. Therefore, SWC_FINVEST was endogenously determined by the linear equation 6.9.

6.2.4. Independent Endogenous Variable and Test for Instruments

The variable financing SWC investment was a dichotomous endogenous variable which took the values between 0 and 1. It was equal to 1 if the household paid the labor to finance SWC investment, and 0 if otherwise. In the sample, 38% of households hired farm labor to finance SWC investments, whereas 62% of households used unpaid labor.

Three variables used as instruments (distance from plot to home, AAECS and plot location) were tested for validity based on a two-stage quantile regression procedure outlined in Kwak *et al.* (2004). For any of these instruments to be valid, they had to be correlated with the variable "SWC_FINVEST". They must also not directly affect household income of any category of farming households, but through other mechanisms including SWC_FINVEST. The study conducted the test of endogeneity by performing a two-stage least squares procedure. In the first stage, we ran the OLS regression of SWC_FINVEST and instruments

on the dependent variable. The obtained R-square of 0.9625 and F-statistic of 519.29 indicate that the correlation between SWC and instruments would yield biased estimates in case of ordinary quantile regression. In the second stage, we ran the 2SLS (the structural equation with IVQR) to estimate between SWC_FINVEST and instruments. Next, we conducted different tests which include endogeneity, first stage regression and overidentification. The test for endogeneity shows large p values indicating that both the Durbin (score) chi2(1) and Wu-Hausman F (1,570) are not significant. We fail to reject the null hypothesis that says that there is an endogeneity problem. To correct the problem of endogeneity, we use IV through the 2SLS. The first stage regression statistics shows a high F value of 14,4731 than the critical values, which indicates that instruments are not weak. The overindentification using the Sargan chi2(1) with 61.02 and Basmann chi2(1) with 62.06 all reported large p values, which means that our model is well specified, and it is valid.

6.3. Empirical results

6.3.1. Descriptive Statistics of Class of Farming Households

Results in Table 6.2. indicate that the average household income was 1340 USD. On average, middle-income earners have more than twice of the household income of the poor. The rich earn three and eight times the household income received by middle-income earners and the poor. There is not much difference in years and number of family labor across the classes of farmers.

The majority of household heads are women for the poor category, whereas there are more men heads in the households under the rich category relative to middle-income earners. The poor category of farmers is less educated, which indicates that they may have lesser knowledge and awareness regarding investment in SWC.

The poor having the least access to off-farm opportunities, limited ownership of assets and livestock may contribute little to household income due to lack of resource endowment and the inability of these farming households to cope with natural disasters. Results show there is less access to input and output and town markets for the poor indicating that they incur more costs due to the high opportunity cost of time. The poor have limited AAECS, while the middle-income earners have medium access, and the rich have diverse access.

Findings imply that the groups still have limited participation and social learning from extension agents. AAECS approach promotes cooperative behavior, facilitates mindset change and information flow while enhancing technology uptake (Teshome *et al.*, 2016). The poor have small farm sizes and use the shortest distance to plot because they operate near the

homestead. These have consequences on their low participation in the commercial production of cash crops such as maize, potatoes, and beans.

Table 6. 2. Descriptive statistics of key variables per categories of farming households

Variable description	Poor	Middle-earners	Rich	Overall
Household income (in USD)	422.26	981.92	2625.01	1340.02
	(61,86.54)	(144.59)	(1431.24)	(1252.59)
Age of the HH head (in years)	47.51	46.97	46.67	47.05
	(17.54)	(14.35)	(13.25)	(15.13)
Household size (numbers)	4.71	5.25	4.88*	4.73
	(0.15)	(0.25)	(0.13)	(2.10)
Sex of household head	0.4893	0.5248	0.5928	0.53
	(0.50)	(0.50)	(0.49)	(0.49)
Years of formal education	3.10	3.48	4.81	3.79
	(2.82)	(3.39)	(4.21)	(3.58)
Occupation of household members	0.14	0.26	0.41	0.27
	(0.35)	(0.44)	(0.49)	(0.44)
Ownership of productive assets (HAI)	3.52	3.74	4.64	3.96
	(1.87)	(1.93)	(2.50)	(2.17)
Livestock ownership (in TLU)	0.76	0.78	1.38	0.98
	(0.05)	(0.13)	(0.06)	(1.02)
Walking distance to the nearest input market (Mn)	30.30	27.29	23.457	27.02
	(31.90)	(26.10)	(47.40)	(36.27)
Walking distance to the nearest output market (Mn)	31.54	38.95	24.114	31.55
	(34.10)	(39.54)	(28.57)	(34.80)
Access to AAECS	0.19	0.26	0.31	0.25
	(0.39)	(0.44)	(0.46)	(0.43)
Proximity to town (walking minutes)	117.5	113.68	99.285	110.18
	(209.52)	(84.49)	(62.51)	(135.36)
Number of plots cultivated by the HH	2.15	2.41	2.79	2.45
	(1.37)	(1.44)	(2.46)	(1.847)
Average walking distance from home to	38.33	49.86	78.51	55.51

plot (in Mn)	(54.4)	(50.34)	(103.8)	(75.3)
Average farm size in square meters	2,762.83 (2,023.95)	5,983.81 (6,7366. 80)	5,409.42 (4,978.80)	2,278.58 (3,8938.40)
Commercialisation of maize produced	0.56 (0.50)	0.63 (0.48)	0.74 (0.43)	0.646 (0.47)
Commercialisation of potatoes produced	0.51 (0.50)	0.58 (0.49)	0.6 (0.49)	0.568 (0.49)
Commercialisation of beans produced	0.76 (0.42)	0.81 (0.39)	0.80 (0.40)	0.78 (0.41)

* Standard deviations are shown in parentheses

6.3.2. Classification of Farming Households per Income Sources

Figure 6.2. depicts three heterogeneous categories of farming households obtained using quantile estimation. Results show that agriculture income and off-farm incomes make the highest of the total household income share for the poor. Agriculture income for the poor category is four and ten times lesser than middle-income earners and the rich categories due to small farm sizes and lack of productive resources.

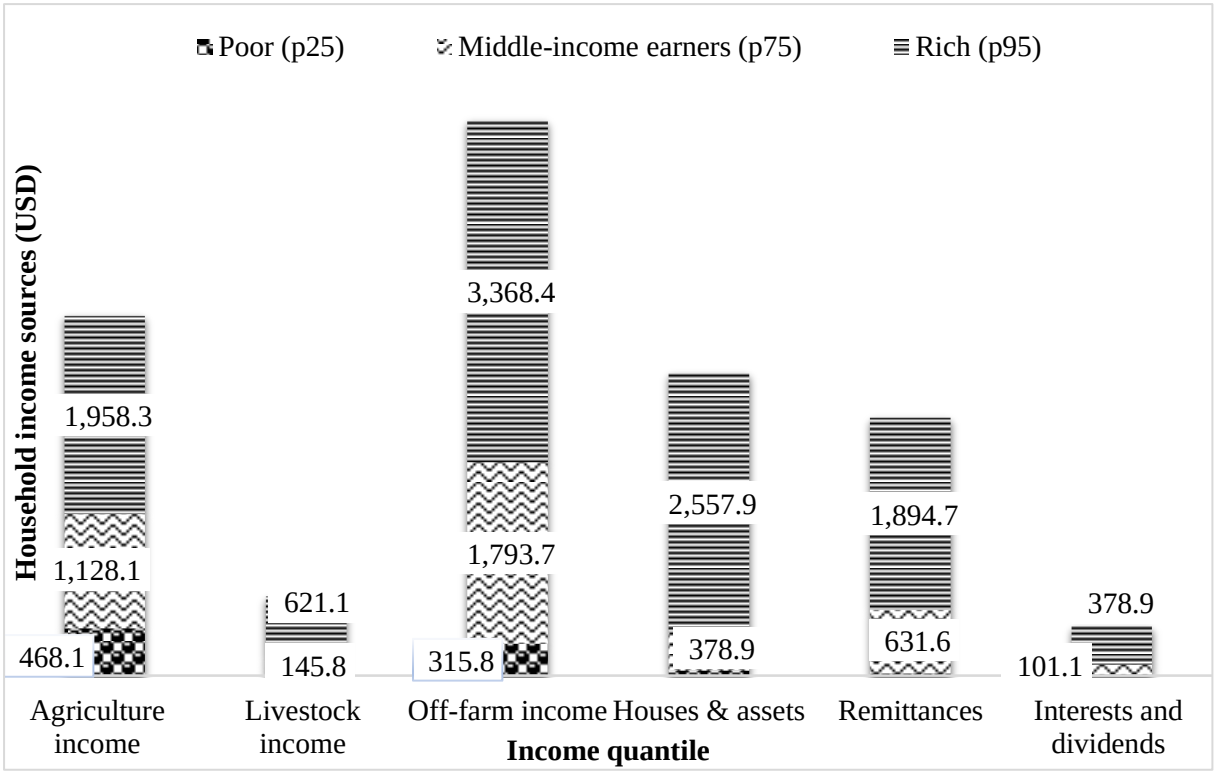

Figure 6. 1. Description of household income per classes based on quantiles

Wage rates for off-farm casual activities are far below the middle-income earners and the rich because of the poor supply of cheap casual labor in agriculture, construction and transport services. For instance, the low income earners mainly serve as bike operators (*Abanyonzi*) or *Karani ngufu* (physical transport of luggage by head). Middle-income earners get wages from off-farm employment in agribusiness and market-oriented cooperatives (Bigler *et al.*, 2017). On top of this, the rich receive high income from rent of assets and transfers (remittances) and savings and dividends. Results highlight the need to improve resource-use efficiency for the poor to commercialization and income diversification to close the income gap between these classes.

6.3.3. Extent of the Use of Soil and Water Conservation, and Soil Fertility Measures

A total of 14 practices of SWC and SF measures were identified in the study area. Figure 6.3 illustrates the extent of use of these conservation measures. Results indicate that about 64% of the cultivated plots had progressive terraces (in form of ridge farming), which are combined with contour bunds with stones, ditches and *Napier grasses*. Approximately, 10% of cultivated plots applied bench terraces. The low use could be linked with gentle slopes of arable farms located at the foot of the volcano park. Bench terraces are constructed on terrain with steeper slopes ranging between 25 to 55 % (Bugenimana *et al.*, 2019).

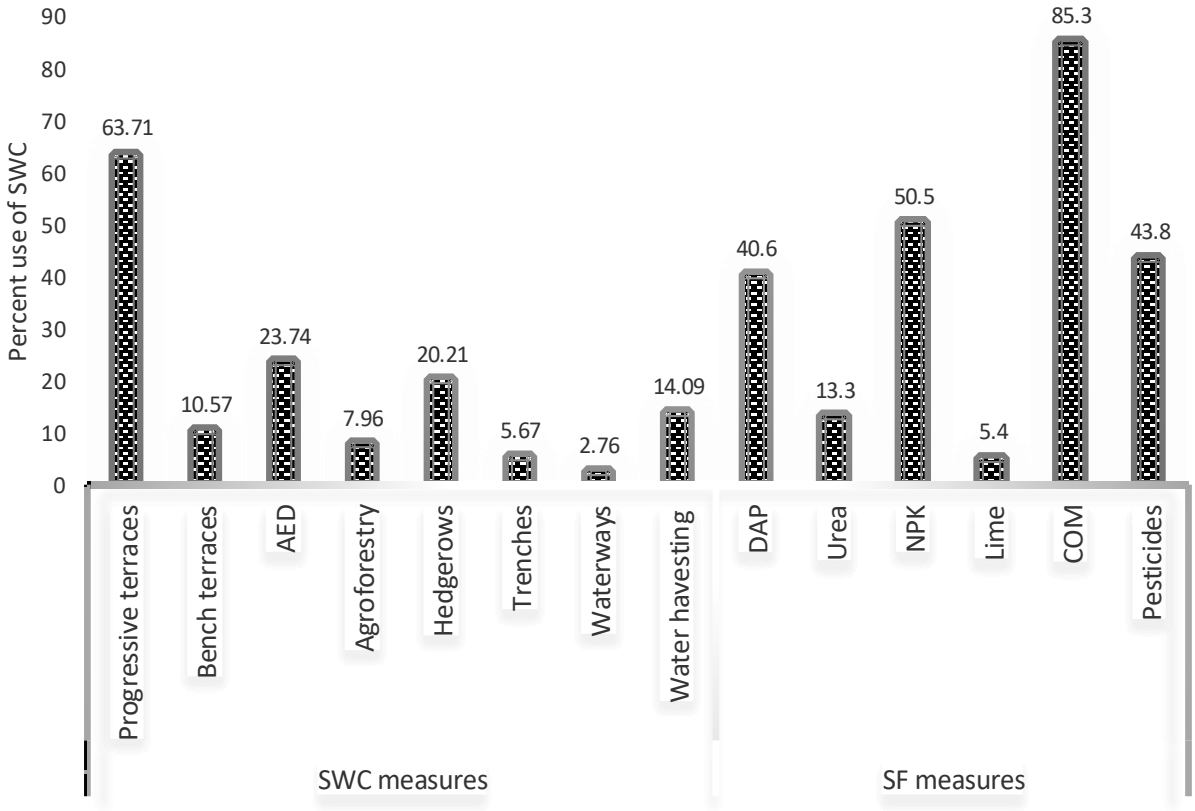

Figure 6. 2. Plot-level use of SWC and SF measures.

Results also reveal that anti-erosion or drainage ditches were used in less than a quarter of cultivated plots, and they consist of horizontal terraces used to limit soil transformations and increase the infiltration of surface water into the subsoil (Sobczuk & Olszta, 2010). The study identified that less than 10% of plots had integrated agroforestry trees and shrubs that contribute to retaining soil nutrients and controls soil erosion. Common trees found in these farms were scattered banana, *French cameron*, *Napier grasses* and eucalyptus. Very few fruit trees could be observed.

Results on plot level use of hedgerows within the farm were estimated at 20%. Hedgerows with trench was used on about 6% of cultivated plots. Continuous cultivation, use of machinery and overgrazing have led to major losses of hedgerows, and hence decline in soil quality and reduction soil water holding capacity (Froidevaux *et al.*, 2019). Loss of hedgerows has contributed to changes in farming practices resulting in decline of farm species and ecosystem services such as pest control and pollination.

Use of waterways or water channels in farms was observed in 2% of the plots cultivated. The channels are surrounded by stone fences and trenches to direct water run-offs

to large water streams (*Imyuzi*) and connected to the foot of the park area. According to Fiener and Auerswald (2017), well-established waterways could effectively prevent and reduce sediment delivery caused by park erosion.

Results indicated that nearly 14% of the households used any type of water harvesting techniques in the farm or in the proximity of their households. Rainwater harvesting is important in solving water shortages for agricultural and domestic use (Ghimire & Johnston, 2019).

The study results show that NPK and DAP were used on 50% and 40% of cultivated plots respectively. Urea was used on less than 15 % of the plots. The proportion of plots that used pesticides was about 44%. The use of lime was very low with only 5% of the plots cultivated. Lime is commonly not used probably because the soil in the region is comparatively fertile and not acidic. Compost and organic manure (COM) were the most applied measures on about 85% of cultivated plots. The use of inorganic fertilizers is still low despite farmers receiving subsidies.

Results indicate that, unlike progressive terraces and COM, the extent of use of other SWC and SF measures is generally low. High use of organic fertilizer indicates farmers' consciousness with organic farming for food production mixed with small quantities of agrochemicals. Improving the involvement of local authorities in SWC extension services could increase awareness of the importance of these techniques for organic farming, soil conservation, and water retention in the volcano region.

6.3.4. Instrumental Variable Quantile Regression and Household Income Effects

The IVQR model indicates that most of the results are robust across the entire sample with 95 confidence intervals. The model fitness test shows that R-square values of 0.2182; 0.2922; and 0.5578 constitute a local measure of goodness of fit for the respective p25; p75; and p95 quantiles. Its fitness is motivated by the familiar R-square of classical least squares regression, which lies between 0 and 1. Thus, the IVQR model indicates the relative success of the corresponding estimates at each specific quantile. The test for correlation between the dependent variable and instruments yielded R-square of 0.07 and F-statistic of 18 suggesting weak identification of instruments. According to Koenker and Basset (1978), the dual inference procedure (with a series of quantile regressions) is robust to weak instruments.

Results of the IVQR model presented in Table 6.3 show that, by controlling for all the covariates, financing SWC investment has a significant positive effect on average annual household incomes of the poor and middle-income earners. However, the effect of financing

SWC investment was not statistically significant for the rich. It could be because the rich have diversified income sources that overshadow income from crop farming. The effect of financing SWC investment leads to a 2 -percentage point increase (0.02) for the poor; and a 10-percentage point increase (0.1) for the middle-income earners. This implies that, from an annual average household income of USD 422.26, financing SWC by the poor would lead to additional USD 21. Middle-income earners would increase average annual income of USD 981.92 by USD 98.2. Thus, the gains received by middle income earners are close to five times greater than those of the poor. Poor farmers operate on small farms as compared to middle-income earners. Consistent with findings by Bigler *et al.* (2017), the poor are more subsistent oriented than middle-income earners who are generally self-employed.

The results reveal that male financing SWC investment has decreasing effects on household income across the three classes. This is probably caused by the fact that farming is becoming less important for men who find more opportunities in the non-farm sector, thus investing in SWC can lead to a loss for the household. Unlike for women, more involvement of men in off-farm activities provides higher household earnings and justifies a transitional process in agriculture.

Table 6.3. IVQR results on heterogeneous effect of SWC investments

HH_INCOME	Poor farmers		Middle- income earners		Rich farmers	
	Coef.	SE	Coef.	SE	Coef.	SE
SWC_FINVEST	0.02** *	0.01	0.10***	0.01	0.02	0.02
Sex	-120.60**	51.19	-284.96***	61.64	-400.44***	134.91
Age	0.36	1.78	0.63**	2.14	14.70 ***	4.69
Household size	-40.09***	11.33	80.61 ***	13.64	-42.22	29.86
Education	5.54	7.70	10.58	9.27	195.91***	20.30
HH occupation	286.33***	54.86	646.58 ***	66.06	-335.18**	144.58
HH asset (log)	227.14***	48.06	197.55***	57.87	378.51***	126.66
Livestock	-75.35**	33.57	116.94***	40.42	368.15***	88.47
Medium AAECS	-195.79***	67.47	127.37	81.23	1,034.13***	177.81
Diverse AAECS	244.34 ***	92.25	111.98	111.07	78.72	243.10
Input market	-2.50***	0.82	-5.29***	0.98	-1.07	2.15
Output market	0.37	0.68	-1.82**	0.82	-7.46***	1.79
Proximity-town	-0.12	0.11	-0.22	0.13	-1.09***	0.29
Bad road	48.13	69.91	-123.06	84.18	-496.72***	84.24
Moderate road	-14.18	78.35	49.93	94.33	373.28*	206.48
Good road	95.97	76.03	-286.62***	91.54	259.64	200.37
Very good road	378.86 ***	82.11	524.24 ***	98.86	975.48 ***	216.39
Farm size (log)	1,042.90***	5.88	738.67***	8.00	739.00***	3.70
Plots	15.05	11.99	-27.37	14.44	135.47 ***	31.61
Maize	229.97***	46.65	329.23***	56.16	-143.94	122.93
Irish potato	169.78***	52.91	176.53***	63.71	257.80*	139.44
Bean	-3.52	62.10	4.02	74.76	-1,494.12***	163.65
Cassava	-142.16	166.53	368.59*	200.51	-1,724.82***	438.87
Coffee	494.96***	111.68	575.53***	134.46	537.25 *	294.32
_cons	218.94	144.68	199.27	174.20	2,382.30 ***	381.29
Sample, N=422	163		163		96	

*, **, *** implies levels of significance at 10%; 5% and 1% respectively.

0.2182; 0.2922; and 0.5578 indicates R-square values respectively for p25; p75; and p95

Notes: + Access to agricultural extension and communication services: medium AAECS and Diverse AAECS

++ Road status: 1. Bad Road, 2. moderately good road, 3. good road; 4. very good road

+++ Commercial crop production: 1. Maize, 2. irish potatoes, 3. bean, 4. cassava, 5. coffee.

For instance, the poor are found as assistant masons (in construction) bicycle taxi drivers or as *Karaningufu* (in transport), where the daily wage rate is almost double of farm wage rates. For the middle-income category, men are in relatively well-paid jobs. The rich are engaged in business or fully employed as primary school teachers, nurses, or local leaders.

The results also suggest that the contribution of women to agriculture is increasing as men are migrating to other forms of employment. The findings corroborate the conclusion by Pattnaik *et al.* (2017) that the process of agriculture transformation is motivated by men's investment in SWC through income from off-farm activities and women's growing contribution to agricultural labor and income decisions. The effect of SWC investment on household income increases gradually and significantly with the age of household head for the middle-income earners and the rich. More age in the highest two classes could be associated with economic stability due to asset accumulation and other earning opportunities. Consistent with Osuji (2019), the increasing effect on income could be linked to farming experience and the ability of old farmers to take up investment decisions.

The effect of financing SWC investment on household income increases significantly with the age of household head for the middle-income category and the rich. Age in the two categories could be associated with economic stability due to asset accumulation and other earning opportunities. Consistent with Osuji (2019), the increasing effect on income could be linked to farming experience and the ability of older farmers to take up investment decisions.

The effect of SWC investment on income decreases with household size for the poor but is significantly positive for the middle-income earners. The poor farmers with many household members may be unable to adequately access the basic needs of life and have fewer opportunities to transform livelihoods. Munanura *et al.* (2016) consider poor households as agents and victims of environmentally degrading activities due to their size and child dependence. The significant positive effect for the middle-income earners suggests that more family members could serve as a source of employment opportunities.

The SWC investment effects on household income were positively linked to levels of education for the rich. It implies that educated people in this class can adopt, invest and diversify strategies. Consistent with Aynalem *et al.* (2019), education may provide better skills for human capital development and motivation for investment in farm and off-farm

activities. Thus, it enhances the ability of a household to make rational decisions and provides opportunities for occupational diversification.

Findings revealed that participation in off-farm occupation has increasing effects on household income for the poor and middle-income earners. However, the effect of financing SWC on income was negatively associated with the participation of the rich. These results on the rich confirms our previous findings that having great diversification strategies could prompt households not to adopt or invest in farming or SWC activities. The small effects for the poor could be attributed to differences in employment conditions, as compared to middle-income earners who are able to finance such an investment through off-farm activities. The poor farmers rely on farm wages for survival. They do have not enough to sustain households and generate additional income. Hence, they require innovations or the creation of new businesses to improve their living standards.

Effects of SWC on household income increases with household ownership of assets. The impact is highest for the rich category, followed by the poor and then middle-income category. The rich smallholders are associated with different livelihood strategies since they can accumulate assets, motivate farm investment, and increases productivity and income (Manlosa *et al.*, 2019). Access to income generation and livelihood diversification opportunities, markets, and essential services can increase access to assets for the poor and middle-income earners.

The impact of SWC investment on household income decreases with livestock ownership for the poor but increases for the rich and middle-income earners. Livestock holding is an important livelihood strategy since it provides manure to fertilise the farm and finances that can be invested in the farm. Due to lack of land, the poor have limited means to feed their livestock, they cannot grow fodder but source it from neighbor's farms. In accordance with Tadesse *et al.* (2019), the intensity of livestock diversification varies between assets for the rich and the poor. Increasing livestock holding is an essential safeguard to income and livelihood loss for the poor and middle-income earners.

Findings indicate a decreasing effect of SWC investment on household incomes with medium access to AAECS for the poor, likely due to limited education skills to grasp extension information. However, there was a positive effect with diverse access to AAECS. This also suggest that the poor may have adequate education extension or information to access investment in complementary innovations that link farm activities to non-farm employment. Kidanemariam (2015) associated access to extension programs with differences

in household welfare and investment in productive assets. The SWC impact on income for the rich was positively significant for medium AAECS signifying minimum effort for communication, mindset change, and technology uptake is required.

The results indicate that the effect of accessing input, output, and town markets on household income is negative across the categories of farming households due to high costs of transports associated with high opportunity costs of farm investment. However, the results show that the middle-income and the rich categories could benefit from easy transport to better markets. Lack of access to proper roads limits the ability of farmers to make high-profit margins. In Rwanda, nearly 40% of the costs of goods are attributed to transport, keeping the prices of inputs high (Kamara *et al.*, 2019). Market linkages create opportunities for non-farm entrepreneurship, influence income of agricultural households and incentivize the cultivation of crops (Pingali *et al.*, 2019).

SWC investment and having more plots had positive effects on the income of the rich only. This finding is attributed to the differences in resource endowment, the scale of operation, and farming conditions between this class and the rest. According to Schulte *et al.* (2018), these factors motivate farmer's investment behaviour and vary significantly with economic and social foundations. Further, the findings reveal decreasing effects of SWC with farm sizes on household income across all the classes, partly due to the inability of the poor to finance farm investments to raise farm productivity. Coupled with agricultural risks, the poor are not able to increase incomes due to small farm sizes (Melketo *et al.*, 2020). The rich probably spend more on buying farm inputs (seeds, fertilizers) or incur higher labor costs than the farm returns.

Results found a positive effect of SWC investment and commercial production of potatoes and coffee on household income in the three classes. SWC effects and maize production on income were positive for the poor and middle-income earners. Non-traditional cash crops (NTAEs) contribute to the asset-building and economic empowerment of various socio-economic classes of farming households. The negative effect for beans and cassava for the rich is probably due to the high costs of inputs and investment. Staple foods such as beans and cassava have a small market share and are characterized by low levels of commercialization (an average of 15% of the harvest) and market participation (Bigler *et al.*, 2017; Louhichi *et al.*, 2019).

6.4. Conclusion and Policy Implications

The study aimed to understand the distribution effects of SWC investment, socio-economic, institutional, and plot-related factors on the income of farming households. The IVQR was used to analyze cross-section data collected from a sample of 422 households. The study tested the hypothesis that financing SWC investment has a positive effect on household income. The quantile estimation was used to classify farming households into the poor, middle-income earners, and the rich.

The results observed high-income gaps between these classes as explained by differences in household sources of income. Findings revealed that the ineffectiveness of SWC investment in the area was due to the low use of SWC and SF measures . The results also indicated that the gains from financing SWC investment for middle-income earners was five times that of the poor. This was attributed to the small scale nature of the farm operation for the poor, reliance on the low farm and casual wages, and lack of assets.

The effect of SWC investment and covariates (including gender, education levels, household size, age) indicates class differences in knowledge, perception, and access to information or innovations to transform agriculture. The indicate an inability of the poor to invest in soil conservation to transform livelihoods due to inadequacy to access basic needs of life. Positive effects of age and SWC investment on household income could be explained by farming experience and economic stability of the older middle-income and the rich farmers. Increasing effects of off-farm occupation and SWC on income could be justified by differences in employment, which suggest that saving and lending innovations or generation of income opportunities for the poor would reduce income gaps between classes and improve their standards. Results also indicate that a lack of extension services could translate into poor skills to grasp extension information for the poor. Access to improved and diverse extension services for the rich could signal that they require minimum effort for communication, mindset change, and technology uptake in SWC.

Decreasing effects of asset ownership and SWC on income indicate that the poor have limited means of production, unlike the rich smallholders who can accumulate assets and motivate farm investment. Effects of SWC investment and commercial production of both NTAEs can contribute to asset-building and economic empowerment of farming households. However, the decreasing effects attributed to SWC and production of maize, beans, and cassava could be attributed to the high costs of inputs and investment.

The study recommends policies that aimed at promoting linkages between SWC investment and income diversification strategies to increase access to assets for the poor and close income gaps among the three farming classes. To improve access to infrastructure and markets, the study suggest that stakeholders should promote programs that facilitate market linkages from farm to non-farm entrepreneurship and incentivize the cultivation of crops. Participation in off-farm occupation opportunities would require diversification strategies such as saving and lending innovations to help the poor finance investment in SWC. To increase adoption of SWC and promote productive diversification, the study recommends policies that improve the efficiency of agricultural extension and communication services involving local authorities., the study recommends the introduction of SWC in production and marketing strategies to increase the productivity and commercialization of cash and staple crops.

Lastly, the IVQR estimation proved to have robustness in the results but with some limitations. However, the study used cross-section data, which makes it complicated to deal with possible endogeneity. Future studies could expand this analysis of quantile treatment using panel data and fixed effects, which can improve the identification strategy. The IVQR method would help to assess the practical policy implications of the long-term effects of SWC investment. Second, measuring household income should be expanded to various income and poverty indicators to study the specific impacts of SWC investment. Finally, the results should not be generalized as the situation of smallholders is basically for farming in the context of Rwanda and Sub-Saharan Africa.

CHAPTER SEVEN
CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions and Policy Implications

Overall, the study has investigated different issues related to gender in SWC, and corresponding pathways to women empowerment and agricultural transformation in Northern Rwanda. The aim of the study was to contribute to sustainable natural resources management and household welfare through enhanced effectiveness of gender preferences and SWC investments in Northern Rwanda. This has been generally addressed by the findings from the specific objectives. First, the study focused on understanding trends in gendered work patterns, perceptions and adoption of SWC practices in relation to agricultural transformation. Second, the study assesses gendered preferences for multiple SWC attributes. Third, it established the interconnection between women's empowerment indicators and soil and water investment strategies. Lastly, the study assessed the impact of financing SWC investment on farm household income.

To provide a more comprehensive analysis understanding of the issues of gender in SWC investment in Northern Rwanda, the study adopted a joint analysis framework combining mixed methods, maximum difference for MNL, ISURE model and IVQR models. Addressing the research aims and data collection required combining both quantitative and qualitative methods of triangulation, drawing on a series of PRA techniques including transect walk, resource mapping, focus group discussion, key informants' interviews; and semi-structured interview. The qualitative survey covered 117 participants. In the quantitative survey, 422 households were selected with 653 male and female respondents and 5,607 farm plots through a multi-stage random sampling technique. Econometric estimation (with (MNL, IVQR and ISURE) and analysis with descriptive, count scores, relative importance of attributes, Pearson correlation were performed using Stata 14.2. Such an assessment was necessary among other efforts to provide recommendations to upscale adoption of SWC investment based on male and female preferences. The study provides significant information regarding the characteristics and drivers of use, adoption of multiple SWC practices, which should help policy makers to design more efficient -women empowerment, production, conservation and livelihood - aimed strategies.

Using the mixed method to asses communities's perception on gendered work patterns, adoption and SWC decision making, the study found that the use and adoption of SC and soil SFM strategies is widespread in the volcano area, but specific adoption rates are

very low for most of practices. Policy makers need to target SWC practices with lower use or adoption rates by providing incentives to farmers to intensify their use. The results also showed that, despite low adoption rates of the practices, farmers' awareness and knowledge is generally undermined. Researches and agricultural extensionists should consider incorporating and integrating indigenous local knowledge with the current technologies during design of production and conservation strategies. This would require, for example, promotion of agricultural extension education targeting women for SWC. Furthermore, the study found that over time gendered work patterns has been characterised by women's deprived access to resources, incentives, and other opportunities including property rights. This reflects social and economic disadvantages that women face currently , which may lead to low adoption of SWC innovations. Hence, the study advocates for change in social norms to encourage shared roles and equal opportunities between men and women in households.

Based on findings from the BWS experiment and MNL model, it was observed that SWC practices adopted at the farm level are heterogeneous in their relative importance, but also independent, interrelated or substitutes in terms of their adoption. This suggests that encouraging each SWC practice or as a bundle/package of SWC of interrelated SC and SFM practices could contribute to upscale intensity, participation and adoption of soil conservation and soil fertility management practices while harnessing the interactions between them. The findings confirm that the benefits associated with synergistic effects or combination of multiple soil conservation and soil fertility practices are high as compared to benefits of a single conservation practice at farm level. Interventions targeting a single adoption model are considerably limited as they may fail to address the required trade-offs and resource efficiency expected from today's farming system. Conservation strategies that promote farmers' adoption of multiple and complementary practices are important to deal with climate smart agricultural constraints. Further, the study found that in relation to economic importance of SWC strategies on HVCs, farmers can make trade-off (substitutability) between more economically viable strategies over less profitable ones.

Furthermore, the study used IVQR to assess household income effects of SWC strategies. It was found that, given the benefits of financing complementary and interdependence SWC investment on the poorest farmers and middle-income earners, policy makers should design production and livelihood strategies that help farmers to earn from off-farm work in order to overcome issues with missing market constraints. Promoting credit incentives and access to finances targeting investment in multiple and complementary SWC

practices could significantly improve the adoption of multiple SWC practices. This could be implemented by providing liquidity that can be used for investment in soil conservation measures and productivity-enhancing inputs.

The study used pro-WEAI and found that financing SWC strategies can provide more economic benefits and fewer opportunity costs as well as exhibit more comparative advantage in producing high-value crops. Based on these results, the study suggests several key frontiers to promote equal women and men participation decisions in farm investment and non-farm employment. The study also recommends that governemtn should take note of the emerging changes in soil management and water conservation patterns and support implementation of production and diversified livelihood strategies. Furthermore, effects of women empowerment indicators on SWC strategies suggest require the design of women empowerment strategies that would help women's massive response to employment opportunities in agricultural commercialisation and off-farm labor markets as a pathway to economic empowerment.

Most importantly, the overall results show that the farmers' preferences, perception use and adoption, and participation decisions in SWC investments are influenced by socio-economic, asset ownership and institutional factors. Promoting trainings and capacity building in resources conservation would lead to greater adoption or investment in SWC. It was also found that the investment and adoption of SWC practices and strategies require important investment from income, off-farm occupation and asset ownership (household, land and livestock; number of plots). However, most practices require a high initial investments which renders the practice less accessible to the poorer farmers. Therefore, program designs should priotitize women and vulnerable farmers (from the poorest to middle income earners). For instance, cash incentives including saving-lending innovations for women and poor farmers would lead to a greater investment in SWC. In particular, social capital, access to agricultural extension and communication, and inclusive market access has considerable impact on SWC investments. The results suggest the need for strengthening institutions and service providers to provide farmers with timely information, inputs, and technical assistance.

7.2. Suggestions for Further Research

The study shows the vital importance of broad and careful data collection and analysis to identify trends, diagnose constraints, and assess policy options. The scope of the thesis allowed for a cross-sectional study. The findings of cross-sectional studies provide much

information, albeit with some caveats. As an example, some farmers may underestimate their investment during the period covered by the study because they might have made SWC investments that are yet to yield return in the short run. Given the dynamic nature of gender resulting in changes in SWC, future studies could consider a longitudinal study that involves repeated observations over time would yield. Longitudinal data provide more opportunities to identify substitutability and complementarities between SWC and SF measures. The study area, particularly Northern Rwanda, is heterogeneous in agro-climatic and livelihood conditions, and hence diversity in adoption of multiple SWC practices. Such heterogeneity would require a new way of thinking of potential cluster differences and implications of policy changes.

An extension of the study would be a simulation analysis for farm investment scenarios and the implication of policy reforms. Another line of analysis would be the use of dynamic models, which would better account for substitution, complementarity, and the process of adaptation. Simulation analysis and dynamic modelling would allow changes in SWC practices and explore different ways to integrate detailed farm-level investment, other attributes, and characteristics in very simplified farm models suitable to provide insights to policy makers.

The use of income measures of poverty which may not reflect other types of deprivation, may provide an incomplete measurement and insufficiency policy guidance. There is, therefore, a need for future studies to examine the impact of SWC/farm investment on the multidimensional poverty status of rural households in Rwanda. The assumption is that, apart from income, many factors, such as the state of health, the level of education, ownership of assets, and access to basic services, would provide sufficient information on well-being and poverty.

Lastly, in line with the above analysis, another aspect to consider in forthcoming studies is the link between gender gaps and income gaps or youth involvement in farm investment and implications of policy reforms within a rural context. Across the study, the empirical analysis shows that men and women are positioned differently in regards to household type and income classes. They have different levels of access, roles, and power positions, therefore, suggesting a need to incorporate intersectionality in all gender and poverty research.

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APPENDICES

APPENDIX A: Participatory rural appraisal checklist

Participatory Rural Appraisal (PRA) will help to identify indigenous current and historical knowledge and gender differentiated perception on SWC technologies, time allocation or labor conditions. The PRA techniques [Transect walk, Participatory mapping and modeling, Timeline (historical mapping), Seasonal calendar (including labor schedule and routines), Venn diagrams] will comprise a wide range of qualitative instruments and observations complemented by Key informants' interview (KIIs) and Focus Group Discussions (FGDs).

Section I: Transect walk

What are SWC technologies do you have in place in this area? How these SWC technologies evolved over time since their introduction (past, present to future trend of SWC technologies)?
What have been the problems associated with establishment, maintenance and management of SWC technologies in this area? What have been proposed solutions?

What do you think were the factors (socio-economic, institutional, and environmental) that have led different stakeholders to invest in SWC conservation technologies?
How can you link the SWC investment patterns and agricultural transformation (food commercialization, market-oriented agriculture, off farm employment, poverty reduction) in your area?

Section II: Participatory mapping and modeling

Din this group, draw a map model current or historical conditions of key features of this area.
What have been the situation regarding land-use patterns, residential areas, changes in farming practices, watersheds, forests and water sources?
In relations to household investment in SWC technologies, what have been changes in regard to farms, home gardens, wealth rankings, household assets, welfare conditions, and the distribution of various resources?

Section III: Timeline (historical mapping)

What were the major historical events (where changes will be dated and listed) related to adoption, use, maintenance and management SWC technologies in this area?

How these key historical events can be used to predict and enhance household investment in SWC technologies in this area (inform future actions)?

Section IV: Seasonal calendar (including labor schedule and routines).

With the help of 12-month calendar starting from last year, in which period do you perform the activities such as farming practices, crop farming, animal fodder or pests, harvesting periods and SWC measures and Soil fertility control measures?
How these activities can be related or have been affected by climate variability factors (rainfall, drought, wind).
What has been the situation of labor allocation, time used for these activities between male, female and the youth in these activities?
How do you relate the decisions on the distribution of income, expenditures and their seasonal variations and constraints between household members (male, female, youth)?

Section V: Venn diagrams

What have been key stakeholders involved in women empowerment and SWC investment interventions in this area.
How can you describe the relationship between different organisations and institutions in the implementation or promotion of women empowerment and SWC investments at household and farm levels?
What was the impact of these stakeholders in regard to agricultural transformation, enhancement of people's social network, available development of infrastructure and input-output markets?

Section VI: Key informants' interview (KIIs) and Focus Group Discussions (FGDs).

How do you perceive SWC patterns and the nature of sate-farmer interaction and social capital for men and women over time?
What is your opinion and perception regarding household investment behavior of various SWC technologies?
What do you think should be the factors that are beyond the immediate control of households (such farm size, assets available to households and the attractiveness of agricultural intensification as a livelihood strategy; and policy and institutional issues) in regard to SWC investments?
How can you describe the historical perspective nature of labor between men and women in SWC technologies, agricultural production systems, gender roles, responsibilities and time spent per activity?

APPENDIX B: Household survey questionnaire

Hello, my name is ……., I am a PhD student at Egerton University, Kenya. I am conducting a research on Intra-household preferences, SWC Investments and Income Poverty Effects. The main purpose is to contribute towards sustainable natural resources management and household welfare through enhanced effectiveness of intra-household preferences and SWC investments in Northern Rwanda.

We are collecting information at household level and we need to have a discussion with you now. if you agree to participate in this survey, we will ask you some questions related to household listing, demographics, employment, and institutional characteristics. We will also present to you questions on Women Empowerment in Agriculture (WEAI), Time allocation for SWC investment, and a choice card for SWC investment options.

Your participation is voluntary and there is no incentive (such as money) provided. The information you will provide will be kept with confidentiality and used only for the research purpose. The survey will take no more than 2 hours.
Do you agree with the consent?
[1] Yes →Continue with survey
[0] No →Stop survey. Thank him/her

First part to be filled by any household decision maker
A: Household characteristics
B: Household listing, demographics and employment
C: Own-account farming (agricultural production, family labor and labor exchanges)
D: Assets & Poverty standards
E: Institutional characteristics & Social network
Second part: to be filled all by both household decision makers
F: Women Empowerment in Agriculture (WEAI)
F: Time allocation for SWC investment
Third part: Best Worst Scaling to be filled all by both household decision makers

HOUSEHOLD TYPE:

1=MALE AND FEMALE ADULT:

The primary decision maker to answer the entire questionnaire (Part 1, Part 2, and Part 3)

The secondary decision maker to answer only (Part 2 and part 3)

2=FEMALE ADULT ONLY:

to answer the entire questionnaire (Part 1, Part 2, and Part 3)

3=MALE ADULT ONLY:

to answer the entire questionnaire (Part 1, Part 2, and Part 3)

PART 3: The whole of it is missing (no choice cards).

MODULE A: HOUSEHOD IDENTIFICATION & LOCATION

A00: Name of Enumerator: …….

A01: Household code: …….

A02: GPS coordinates**: Lat …… Lon…….**

A03: District …….

A04: Sector: …….

A05: Cell: ……...

A06: Type of household (1. Male-headed, 2. Female-headed, 3. Child-headed)

A07: Name of the respondent: ……. …… Sex: ……

A08: Name of the primary decision maker: …… Sex: ……

A09 Name of the secondary decision maker: …… Sex: ……

A10: Phone number:

A11: Note here if the household has participated in the previous survey: …….

PART ONE: ***The respondent in this part is one of the two main decision makers in the household.***

MODULE Ba: HOUSEHOLD LISTING, DEMOGRAPHICS AND EMPLOYMENT (REQUIRED).

*Enumerator: Ask these questions about all household members. A*sk about each member in household. Please list the names of all member of the household, starting with the primary respondent.

Name of household member? [start with primary respondent, continue with the secondary respondent, and other members in descending order of age]	What is [NAME's] sex? 1 = M 2 = F	What is [NAME's] relationship to the primary respondent? CODE 1	What is [NAME's] age? (in complete years)	What is [NAME's] marital status? CODE 2	Is [NAME] currently attending school this year? 1 = Yes 0= No	Can [NAME] read and write? CODE 4	How many years of education were completed by [NAME]? CODE 5	Does [Name] have any occupation or paid activities, outside of your own farm
B01	B02	B03	B04	B05	B06	B07	B08	B09

Code 1: Codes for respondent (relation with hh heads)	**Code 2: (B05)**	**Code 4 (B07): Literacy**	**Code 5: (B09) Education level**	
[1] HH Head [2]Spouse [3] Child [4] None [5] Other (specify): ……..	1. Single/never married 2. Divorced 3. Separated 4. Widowed 5. Religious marriage 6. Civil marriage 7. Cohabiting 8. Offical marriage	1. Cannot read nor write 2.Can sign (write) only 3. Can read only 4. Can read and write	[0] None [1] Primary 1 [2] Primary 2 [3] Primary 3 [4] Primary 4 [5] Primary 5 [6] Primary 6 [7] Ordinary level 1	[8] Ordinary level 2 [9] Ordinary level 3 [10] Secodary 4 [11] Secodary 5 [12] Secodary 6 [13] Teritiary- (post primary) [14]Teritiary- (post-secondary) [15] University

Module Bb Production and income: Wage and self-employment and employment conditions:

Hh Id	Name of household member?	Describe all of the occupations / paid activities on which you have worked during the past 12 months CODE 1	Do you/does your household own most of the means of production other than land used to perform this activity? 1: Yes 0: No	Who is the employer? Code 5	Is this activity in the agricultural sector for exports? 1: Yes 0: No	Which months have you worked for this particular activity in the last 12 months?	Usually, how many working days per month?	Usually, how many working hours per day of work?	Does this job involve migration to other regions / areas? Code 3	If yes, where? (Countries, regions, etc.)	If yes, indicate month(s) with migration (months away)	How long is your usual commute to your work place (one way, in minutes)?	How much do you usually pay for transportation (one way)?	If self-employment, what is the income that you receive from this activity? If not self employed	If paid, what is the basis of payment? Code 6	In what unit are you paid? 1) in cash 2) in kind 3) other, please specify	How much are you paid per Specify
	Bb1	Bb2	Bb3	Bb4	Bb5	Bb6	Bb7	Bb8	B9	Bb10	Bb11	Bb12	Bb13	Bb14	Bb15	Bb16	Bb17
1																	
2																	
3																	
4																	
5																	

6																	
7																	
8																	
9																	
10																	

Code 1 (country-specific)		Code 3	Code 5	
1. Touristic sector 2. Extractive sector 3. Agricultural worker 4. Fishing 5. Construction sector 6. Teaching / School work 7. Driver 8. Office worker 9.Army / Police	10. Retail sector 11. NGOs / cooperative 12. Local/central administration 13. Mechanic/garage worker 14. Government. Public Sector 15. Domestic work for another household (e.g. gardener, cleaner, nanny) 16. Other, specify	1: yes 0: no	1.NGO project 2.Government project 3.Individual 4.Cooperative 5.Private company 6. Self-employment	1) Daily wage 2) 15 days intervals 3) Monthly wage 4) Based on specific contract/work/service 5) Piece or task rate wages (per specific quantity or completed task) 6) On commission (percentage of profits/sales) 7) Other, please specify

Module Bc: Own-account farming (on owned and rented land): crop production by the household

1																
2																
3	Main crops cultivated by the household during last year (2017)	Area cultivated Ha	Total production Kg	Production kept by the household for own consumption Kg	Production sold Kg	Production kept for seed production Kg	Production kept for storage. (more than 1 month). Kg	Where & to whom was it sold? Most important source Code 2	What was the Price per kg sold?	How was the price determined (Code 3)	Where & to whom was it sold? (If more than 1 answer) Code 2	What was the Price per kg sold?	How was the price determined (Code 3)	When where you paid? Code 4	For this crop, do you have access to specific production label a) organic b) Fairtrade c) both d) other (specify)	
4																
5																
6																
7																
8																
9																
10																
	Code1: Crops cultivated (C09)						Code 2: Market				Code 3: Price negotiated				Code 4	
	Ca01	Ca02	Ca04	Ca05	Ca06	Ca07	Ca08	Ca09	Ca10	Ca11	Ca12	Ca13	Ca14	Ca15	Ca16	

1: Maize 2:Irish Potatoes 3: Beans 4. Peas 5. Pyrethrum 6. Coffee 7.Banana 8. Cassava 9. Wheat 10. Sweet potatoes		1: Market 2. Cooperative 3. State - regional authority 4. Private company 5. Other intermediary (middle men) 6. Family / friends or other personal relations.	1. By the farmers (your household, a cooperative or similar) 2. By the buyers 3. Mutually by 1 and 2 4. We took the current market price 5. Other (specify)	1. Before the harvest 2. Upon the delivery of the product 3. More than one month after the delivery of the product 4. Other, specify

Module Bd: Own-account farming (on owned and rented land): employment creation

For the most important cash crop as well as for the most important subsistence crop, please indicate the information on working time spent

ID CODE	Crop / Agricultural activity CODE 4	What are the months in which said activity is performed?	Who are the people from the household participating in said activity?	Usually, how many working days are spent on this activity?	Does the household pay non-household members for this activity? If yes, how many people?	What is the gender of these worker(s)? 1: Male 2: Female	Usually, how many working days are spent on this activity?	What is the basis of payment? CODE 8	In what unit are you paying? 1) in cash 2) in kind 3) other, please specify	How much are you paying per [basis of payment]? Specify (0= unpaid is possible)	Does your household provide some extras: food/drinks, health insurance, and / or transport? Code 6	Does the household use any unpaid work by non-household members for this activity?	What is the gender of these worker (s)? 1: Male 2: Female	Usually, how many working days are spent on this activity (per person per month)?	Do you provide anything in return? Code 9
	Cc1	Cc2	Cc3	Cc4	Cc5	Cc6	Cc7	Cc8	Cc9	Cc10	Cc11	Cc12	Cc13	Cc14	Cc15
1															
2															
3															
4															
5															
6															

7															
8															
9															

Code 4	Code 5	Code 6	Code 8	Code 9
1. Land preparation 2. Sowing 3. Weeding 4. Harvesting 5. Post-production work 6. Livestock production	1. Family members outside of household. 2. Friends 3. Worker from the village 4. Worker from outside the village	1. Meal / drinks 2. Insurance (health or accident) 3. Transports (daily traveling from home) 4. Pre-paid card (phone) 5. Housing 6. Other Specify	1) Daily wage 2) 15 days intervals 3) Monthly wage 4) Based on specific contract/work/service 5) Piece or task rate wages (per specific quantity or completed task) 6) On commission (percentage of profits/sales) 7) other, please specify	No Yes Cash Goods Labor Other, specify

Module Be: Unpaid work outside the household (labor exchanges)

N/S	Cd1 Name of household member? [start with primary respondent, continue with the secondary respondent, and other members in descending order of age]	Cd2 Do you do any unpaid work for other households? Describe the activity [Code 1; use agricultural activities codes, add codes 11 to 13.)	Cd3: Who do you work for? Code 2	Cd4: Do you receive anything in return? Code 3	Cd5 Which months have you worked for this particular activity in the last 12 months? Multiple choice answer: whole year and list of months	Cd6: Usually, how many working days per month?	Cd7 Usually, how many working hours per day of work?
1							
2							
3							
4							
5							
	1. Land preparation 2. Sowing 3. Weeding 4. Harvesting 5. Post-production work 6. Livestock production		Code 2 1. Family (sons of respondent or of his/her spouse) 2. Family (daughter of respondent or of his/her spouse) 3. Family (father of respondent or of his/her spouse) 4. Family (mother of respondent or of his/her spouse)		Code 3 No Yes Cash Goods Labor Other, specify	Code 4: Whole year 201-2019 September 2018 October 2018 Novemeber 2028 December 2018 January 2019 February 2019 March 2019	

		5 Friends 6: Cousins / other relatives 7. Neighbours 8 Other(specify)		April 2019 May 2019 June 2019 July 2019 August 2019

Module Bf: Land use and land rights

ID CODE	Land and access to land for production	Total area of land (in ha)	Area used for crop production? (in ha)	Area used for livestock production? (in ha)	Type of ownership / Access Code 1	Who is the owner of that land? Code 6	Who is going to inherit this land? Code 7	Who receives the bigger share? Code 7	How did you acquire this (these) piece of land?	How much did you spend to acquire this land?	Who did you sell from/to? Code 3	What is the basis of payment? Code 4	In what unit are you paid/ do you pay? Code 5	How much are you paid per/do you pay per [basis of payment]?Specify
		a	b	c	D	e	f	g	h	i	j	k	l	m
Da1	Does your household													
Da2	Has your household sold any													
Da3	Does your household													
Da4	Does your household													
Da5	In addition to owned													

Code 1		Code 2	Code 3	Code 4	Code 5	Code 6	Code 7

1: Ownership with official title 2. Ownership without title 3. Share of community ownership 4. Other, specify	1. Inheritance 2. Gift / Donation 3. Purchased 4. Exchange 5. Dowry 6. Other / specify	Cooperative: Private person: Company: Government	1) daily 2) monthly 3) annually 4) other, please specify	1) in cash a. fixed amount b. share of sales value 2) in kind a. fixed amount b. share of output volume 3) labor 4) other, please specify	1. Husband 2. Wife 3. Both 4. Other, specify	1. Son(s) 2. Daughter(s) 3. Spouse 4. Family of spouse (male head of household) 5. Family of spouse (female head of household) 6.. Other, specify	

Module Bg: Agricultural assets and practices

Db. Agricultural practices and inputs	Yes / no 1= yes 0=no	Agricultural Tools Code 2	Quantity	Age	Number of years	Quality	New/used 1=new 0=used
DbX	DbX		DbbXa	DbbXb	DbbXc	DbbXd	DbbXe
Do you use or have		Do you own?		How many years ago did you acquire it?		Was it new or used?	
Pesticides		Dbb 1: Plough					
Hybrid seeds		Dbb 2: Axe					
Seed from previous year		Dbb 3: Plumbing Machine					

Tractor service (renting tractors)		Dbb4: Tractor					
Manure		Dbb 5: Threshing machine					
Mulching		Dbb 6: Cart					
Ox Plough		Dbb 7: Spray machine					
Irrigation for crops		Dbb 8: Hoe / Fork					
Seed storage facilities		Dbb 9: Miller		**Code2: Tools (D02)** 1: Plough 2: Axe 3: Plumbing Machine 4: Tractor 5: Threshing machine 6: Cart 7: Spray machine 8: Hoe / Fork 9: Miller 10: Wood tray 11: Cement dried ground 12: Lawnmower 13. Other / specify			
chemical fertilizers		Dbb 10: Wood tray					
Grain storage facilities		Dbb 11: Cement dried ground					
Other agricultural equipment's (specify)		Dbb 12: Lawnmower					
Access to extension services?		Dbb 13. Other / specify					

Module Bh: Livestock, agricultural production: Transformation and added value from agricultural assets

	Do you have any livestock? List the livestock of the household in the following table										
	ID	Quantity/number	How many of this livestock did you consume in the last 12 months?	How much livestock did you sell in the last 12 months	Db21 Income derived from assets	Income	C I D	Type of ownership / Access Code 1	Income	Do you rent out any house, apartment or room?	Income per month or year
										Do you rent out any other assets (e.g. tractor, vehicles, mill etc.).	Income per month or year
		a	B	c							
Db2_1	1: Cows				Dbb22	How much income did you get last year from selling your livestock?					
Db2_2	2: Oxes										
Db2_3	3: Pigs				Db23	How much income did you get last year from selling products DERIVED from your livestock? (example: eggs, wool,					
Db2_4	4: Goats				Db24	How much money did you spend last year to buy new or additional livestock?					
Db2_5	5: Sheep				Db25	How much money did you have to spend for your livestock last year? (veterinary, feedings, etc)					
Db2_6	6.Chicken/pigeons										

Db2_10 i	10 Other (specify).					

Module Bi: Assets: Financial Capital

ID	Financial flows / credit			Debts	
1	Do you or anybody in this household receive any remittances or other transfers (e.g. cash transfers) (If No, SKIP to 5) (more than one answer	1=yes 0=no	11	Do you have debts?	1=yes 0=no
2	Who is sending you this money? CODE 1		12	If yes, to whom? CODE 2	
3	How much do you receive (per month, if yearly estimate ADD UNIT)	XX / Month	13	And how much?	
4	Do you have to fulfill any conditions in order to	specify	14	Do you SEND some remittances?	1=yes; 0 No
5	Do you have access to credit?	Yes/No	15	If yes to whom? CODE 1 : And how much	
6	If yes, from whom? CODE2		16	Are you a member of any informal saving	Yes/No
7a	Do you have savings?	Yes / no	17	Do the members of your HH have health insurance? Code 3	
7b	How much do you save per year?		18	Do you have any other insurance? (e.g. agricultural insurances)	Yes/No
8a	Do you have any Bank Account?	Yes/No	19	… if yes, specify	
8b	Who is the holder's name of a bank account		20	Do you have any other source of regular income? Code 2: Interest payments	Income per month or year
9	Do you have debts?	1=yes	21		

Code 1:Remittances and Direct Payment			**Code 2: Credit**	**Code 3: Insurances**

Remitances: 1. Family (sons of respondent or of his/her spouse) 2. Family (daughter of respondent or of his/her spouse) 3. Family (father of respondent or of his/her spouse) 4. Family (mother of respondent or of his/her spouse) 5 Friends 6: Cousins / other relatives 7. Other(specify)	Other transfers: 1.NGO project 2.Pension fund 3. Government subsidies 5. Cooperative 6. Religious group 7. Other, specify	1: Bank / formal institution 2: Informal schemes (money lender) 3. Family / friends/ neighbors 4. NGOS 5. Local or national government 6. Customary Credit system 7. Village fund 8 Cooperative 9. State (e.g. pension funds) 10. Other(specify)	1. Yes All the household is insured 2. Yes. But not everybody in the HH is insured 3. Yes. (but only me) 4. No 5. other (specify)

Module Bj: Institutional factors (Social network) & Market Access

ID	Presence of SWC, gender empowerment assisted public- private programs and agri-extension services	Answers/code
1	Do you or anybody in this household receive any public- private programs SWC assisted program in the area?	1=yes 0=no
2	Do you or anybody in this household receive any public- private programs assisted gender empowerment program in the area?	1=yes 0=no
	Do you or anybody in this household receive any Agri-extension services?	

3	Farmers' sources of first information about Improved varieties, SWC measures and SF measures	Farmers (FFS) Neighbors Government extension officer Extensionist from development agencies
4	How many times did you receive information or assistance from public- private	**Time** Number of hours per day Number of days per week Number days per month
5	How many times did you receive information or assistance from public- private programs gender empowerment program in the area?	
6	How many times did you receive information or assistance from Agri-extension services?	
7	How many times did you receive information about: Improved varieties, SWC measures and	
8	Input and output market channels	Distance to nearest input market (km) Distance to nearest output market (km) Access to guaranteed output market (have/not have contract) Proximity to town (meters)
9	Infrastructure condition	State of road to nearest market (ranking: 1-5) Very bad Bad Moderately good Good

PART TWO: PROJECT LEVEL WOMEN EMPOWERMENT IN AGRICULTURE (pro-WEAI)

Module C: WOMEN EMPOWERMENT IN AGRICULTURE (WEAI)

MODULE C1: ROLE IN HH IN DECISION-MAKINGAROUND PRODUCTION & INCOME GENERATION: Input in productive decisions				
Activity		Did you (singular) participate in [ACTIVITY] in the past 12 months (that is during the last [one/two] cropping seasons)? Yes 1 No 2 >> next activity	How much input did you have in making decisions about [ACTIVITY]?	How much input did you have in decisions on the use of income generated from [ACTIVITY]
Activity code	Activity description	C2.01	C2.02	C2.03
A	Food crop farming			
B	Cash crop farming			
C	Livestock raising			
D	Maize production management practices			
E	Climbing bean production management practices			
F	Irish potatoes production management practices			
G	Purchase of agricultural inputs			
H	Non-farm economic activities			
I	Food processing and marketing			
J	Employment outside agriculture			
K	Progressive terraces (management)			
L	Bench terraces (management or construction)			
M	Agro forestry management practices			
N	Hedges on rows (within the farm)			

O	Hedges coupled with trenches			
P	Water ways and channels within farms			
Q	Water harvesting management			
R	Cultivation techniques (e.g: mono or mixed cropping, rotation, etc)			
S	Tree plantation			
I	Wage and salary employment			

C2.02/C2.03: Input into decision making:
1. No imput……..1
2.Input into very few decisions……2
3.Input into some decisions……..3
4.Input into most decisions……4
5.Input into all decisions……..5
6. No decision made.....6
7.Not applicable 88
8. I do not know…….....99

MODULE C5: DECISION MAKING: Input in productive decisions

ENUMERATOR: Ask C5.01 for all categories of activities before asking C5.02. Do not ask C5.02 if C5.01 response is 1 and respondent is male OR C5.01 response is 2 and respondent is female. If household does not engage in that particular activity, enter 98 and proceed to next activity.		When decisions are made regarding the following aspects of household life, who is it that normally takes the decision?	To what extent do you feel you can make your own personal decisions regarding these aspects of household life if you want(ed) to? Ask only if C5.01 is 1 and respondent is female, C5.01 is 2 and respondent is male, or C5.01 is 3-7.
Activity code	Activity description	C5.01	C5.02
A	Food crop farming		
B	Cash crop farming		

C	Livestock raising		
D	Maize production management practices		
E	Climbing bean production management practices		
F	Irish potatoes production management practices		
G	Purchase of agricultural inputs		
H	Non-farm economic activities		
I	Food processing and marketing		
J	Employment outside agriculture		
K	Progresssive terraces (Management)		
L	Bench terraces (Management)		
M	Agro forestry management practices		
N	Hedges on rows (within the farm)		
O	Hedges coupled with trenches		
P	Water ways and channels within farms		
Q	Water harvesting management		
R	Cultivation techniques (e.g: mono or mixed cropping, rotation, etc)		
S	Tree plantation		
C5:01: Who makes decision: Main male or husband ……..1(if MALE) Main female or wife……..……2(if FEMALE) Husband and wife jointly……..3 Someone else in the HH…….4 Jointly with someone else in the HH…….....5 Jointly with someone else outside the HH……....6 Someone outside the HH/other.....7 HH does not engage in activity/Decision is not made…….....98			C5:02: Extent of participation in decision making: Not at all……..1 Small extent …….2 Medium extent……3 To a high extent……4

MODULE C5: MOTIVATION FOR DECISION MAKING: Autonomy

ENUMERATOR: This set of questions is very important. I am going to give you some reasons why you act as you do in the aspects of household life I just mentioned. You might have several reasons for doing what you do and there is no right or wrong answer. Please tell me how true it would be to say: [If household does not engage in that particular activity, enter 98 and proceed to next activity.]		My actions in [ASPECT] are partly because I will get in trouble with someone if I act differently. [READ OPTIONS: Always True, Somewhat True, Not Very True, or Never True]	Regarding [ASPECT] I do what I do so others don't think poorly of me. [READ OPTIONS: Always True, Somewhat True, Not Very True, or Never True]	Regarding [ASPECT] I do what I do because I personally think it is the right thing to do. [READ OPTIONS: Always True, Somewhat True, Not Very True, or Never True]
Activity code	Activity description	C5.03	C5.04	C5.05
A	Food crop farming			
B	Cash crop farming			
C	Livestock raising			
D	Maize production mgt practices			
E	Bean production management practices			
F	Potatoes production mgt practices			
G	Purchase of agricultural inputs			
H	Non-farm economic activities			
I	Food processing and marketing			
J	Employment outside agriculture			

K	Progressive terraces (management)			
L	Bench terraces (management)			
M	Agro forestry management practices			
N	Hedges on rows (within the farm)			
O	Hedges coupled with trenches			
P	Water ways and channels within farms			
Q	Water harvesting management			
R	Cultivation techniques (e.g: mono or mixed cropping, rotation, etc)			
S	Tree plantation			
			C5.03/C5.04/C5.05: Motivation for activity: Never true…….1 Not very true…….....2 Somewhat true.....3 Always true .....4 Household does not engage in activity…....98	

MODULE C3: ACCESS TO PRODUCTIVE CAPITAL: Ownership of assets

Productive capital		Does anyone in your household currently have any [ITEM]? Yes…….1 No……..2>>>next item	How many of [ITEM] does your household currently have?	Who would you say owns most of the [ITEM]?
Activity code	Productive capital	C5.01a	C3.01b	C3.02
A	Agricultural land (Piesces/plots)			
B	Large livestock (cattle)			

C	Small livestock (goats, pigs, cheep)			
D	Chickens, Ducks, Turkeys, Pigeons			
E	Fish pond or fishing equipment			
F	Farm equipment (non-mechanized)			
G	Farm equipment (mechanized)		E3.02-E3.06: Decision-making and control over productive capital Self……1 Partner/Spouse ……...…….2 Self and partner/spouse jointly……..3 Other household member …….. ……..4 Self and other household member(s)…….5 Partner/Spouse and other household member(s)…….6 Someone (or group of people) outside the household.....7 Self and other outside people……...8 Partner/Spouse and other outside people……9 Self, partner/spouse and other outside people.....10	
H	Nonfarm business equipment			
I	House (and other structures)			
J	Large consumer durables (fridge, TV, sofa)			
K	Small consumer durables (radio, cookware)			
L	Cell phone			
M	Other land not used for agricultural purposes (pieces, residential or commercial land)			
N	Means of transportation (bicycle, motorcycle, car)			

MODULE C3: ACCESS TO PRODUCTIVE CAPITAL: Purchase, Sale or Transfer of assets						
Productive capital		Does anyone in your household currently have any [ITEM]? Yes……1 No……..2>> >next item	Who would you say can decide whether to sell [ITEM] most of the time?	Who would you say can decide whether to give away [ITEM] most of the time?	Who would you say can decide to mortgage or rent out [ITEM] most of the time?	Who contributes most to decisions regarding a new purchase of [ITEM]?
Activity code	Productive capital	C5.01a	C3.03	C3.04	C3.05	C3.06
A	Agricultural land (Piesces/plots)					
B	Large livestock (cattle)					
C	Small livestock (goats, pigs, cheep)					
D	Chickens, Ducks, Turkeys, Pigeons					
E	Fish pond or fishing equipment					
F	Farm equipment (non-mechanized)					
G	Farm equipment (mechanized)		C3.02-C3.06: Decision-making and control over productive capital: Self……1 Partner/Spouse ……...…….2 Self and partner/spouse jointly…….3 Other household member …….. …….4 Self and other household member(s)……5			
H	Nonfarm business equipment					
I	House (and other structures)					
J	Large consumer durables (fridge, TV, sofa)					
K	Small consumer durables					

	(radio, cookware)		Partner/Spouse and other household member(s)…….6 Someone (or group of people) outside the household.....7 Self and other outside people……8 Partner/Spouse and other outside people……..9 Self, partner/spouse and other outside people.....10
L	Cell phone		
M	Other land not used for agricultural purposes (pieces, residential or commercial land)		
N	Means of transportation (bicycle, motorcycle, car)		

MODULE C3: ACCESS TO CREDIT				
Lending source		Has anyone in your household taken any loans or borrowed cash/in-kind from [SOURCE] in the past 12 months?	Who made the decision to borrow from [SOURCE]?	Who makes the decision about what to do with the money/ item borrow from [SOURCE]?
Activity code	Productive capital	C3.07	C3.08	C3.09
A	Non-governmental organization (NGO)			

B	Informal lender			
C	Formal lender (bank/financial institution)			
D	Friends or relatives			
E	Group based micro-finance or lending including VSLAs / SACCOs/ merry-go-rounds			
		C3.07 Taken loans: Yes, cash 1 Yes, in-kind 2 Yes, cash and in-kind 3 No 4 >> C3.11A Don't know…5 >> C3.11A	C3.08-C3.09: Decision-making and control over credit: Self……1 Partner/Spouse ……...…..2 Self and partner/spouse jointly……...……3 Other household member……..4 Self and other household member(s).……5 Partner/Spouse and other household member(s)…….6 Someone (or group of people) outside the household...7 Self and other outside people……....8 Partner/Spouse and other outside people….9 Self, partner/spouse and other outside people.....10	

MODULE C5: DECISION MAKING: Control over use of income		
ENUMERATOR: Ask C5.01 for all categories of activities before asking C5.02. Do not ask C5.02 if C5.01 response is 1 and respondent is male OR C5.01 response is 2 and respondent is female. If household does not engage in that particular activity, enter 98 and proceed to next activity.	When decisions are made regarding the following aspects of household life,	To what extent do you feel you can make your own personal decisions regarding these aspects of household life if you want(ed) to?

		who is it that normally takes the decision?	Ask only if C5.01 is 1 and respondent is female, C5.01 is
Activity code	Activity description	C5.01	C5.02
A	Getting inputs for agricultural production		
B	The types of crops to grow for agricultural production		
C	Taking crops to the market (or not)		
D	Livestock raising		
E	Your own (singular) wage or salary employment		
F	Major household expenditures (such as a large appliance for the house like refrigerator)		
G	Minor household expenditures (such as food for daily consumption or other household needs)		
H	Non-farm economic activities		
I	Food processing and marketing		
J	Employment outside agriculture		
C5.01: Who makes decision Main male or husband……1 (if MALE) Main female or wife ……....2 (if FEMALE) Husband and wife jointly……3 Someone else in the household……4 Jointly with someone else inside the household……5 Jointly with someone else outside the household……6 Someone outside the household/other……7			C5.02: Extent of participation in decision making Not at all ……1 Small extent……..2 Medium extent……..3 To a high

Household does not engage in activity/Decision not made…….98	extent……4

MODULE C4: GROUP MEMBERSHIP AND INFLUENCE IN THE GROUP

Group Membership		Is there a [GROUP] in your community? Yes 1 No 2 >> next group	Are you an active member of this [GROUP]? Yes 1 No 2
Activity code	Group categories	C4.01	C4.02
A	Agricultural / livestock/ fisheries producer's/ marketing groups		
B	Water users' group		
C	Forest users' group		
D	Community based natural resources management group		
E	Credit or microfinance group (SACCOs/merry-go-rounds/ VSLAs)		
F	Mutual help or insurance group (including burial societies)		
G	Trade and business association		
H	Civic groups (improving community) or charitable group		
I	Local government		
J	Religious group (choir, prayer groups, church action groups)		
K	Other women's group (only if it does not fit into one of the other categories)		
L	Other (specify)		

MODULE C4: INDIVIDUAL LEADERSHIP AND INFLUENCE IN THE COMMUNITY: Speaking in public

Qno	Question	Response	Response code

C4.03	Do you feel comfortable speaking up in public to help decide on infrastructure (like small wells, roads, water supplies) to be built in your community?		No, not at all comfortable …………………………1 Yes, but with a great deal of difficulty………..2 Yes, but with a little difficulty……………………3 Yes, fairly comfortable………………………………4 Yes, very comfortable………………………………..5
C4.04	Do you feel comfortable speaking up in public to ensure proper payment of wages for public works or other similar programs?		
C4.05	Do you feel comfortable speaking up in public regarding the crop to cultivate in the consolidated land		
C4.06	Do you feel comfortable speaking up in public giving your ideas in local meeting?		
C4.07	Do you feel comfortable speaking up in public to protest the misbehavior of local authorities or elected officials in this cell?		

MODULE C4: TIME USE

	Activity	24-hour time diary																																													
		1				2				3				4				5				6				7				8				9				10				11				12			
A	Sleeping and resting																																																
B	Eating and drinking																																																
C	Personal care																																																
D	School (also homework)																																																
E	Work as employed																																																
F	Own business work																																																
G	Farming/livestock/fishing																																																
J	Shopping/getting service (incl																																																
K	Weaving, sewing, textile care																																																
L	Cooking																																																

M	Domestic work (incl fetching																																																
N	Care for children/adults/elderly																																																
P	Travelling and communiting																																																
Q	Watching TV/listening to																																																
T	Exercising																																																
U	Social activities and hobbies																																																
W	Religious activities																																																
X	Other, specify …																																																

D: TIME ALLOCATION FOR SWC INVESTMENT

D1: Plot location and SWC investments

	How many plots in total do you or someone else in this HH [cultivate]? (Number)	Describe the location of each of the ${plot} mentioned	What is the distance from your home to the location of each of the ${plot} mentioned? (in Km)	What is the slope of the $[plot} in {location}	What is the size of the $[plot} in {location} (meters)	Which crop did you cultivate on this ${plot} during ${season}	On this ${plot} did you use any of the following ${swc measures)	How many/ long of this ${SWC measure} do you have in your {plot} in ${ location} (number, size)	In the last two seasons, did you apply any of the following soil fertility control measures	What quantity of the ${SFC measure } did you apply on this {plot} in {location} (Kgs)	How many people in your HH participated in construction/maintenance of this ${swc measures} on ${plot} ?	Did you personally participate in construction/maintenance of this ${swc measures} on ${plot} ? No [0] Yes [1]
Code	01	02	03	04	05	06	07	08	09	10		**11**
1												
2												
3												
4												
5												
	02 Location: 1.Sector		04 Slope: 1. Gentle slope		05 Crop names: 1. Maize		07 SWC measures: 1. Progresssive terraces				**06 Seasons:** **Season 2019A**	

	2. Cell 3. Village	2. Moderately steep slope 3.Very steep slope	6. Coffee 2. Irish Potatoes 7. Banana 3. Beans 8. Cassava 4. Peas 9. Wheat 5. Pyrethrum 10. Sweet potatoes	2. Bench terraces 3.Anti erosion ditches 4.Agro forestry 5. Hedges on rows (within the farm) 6.Hedges coupled with trenches 7.Water ways and channels within farms 8.Water harvesting management	**Season 201B**

D2: Household time allocation for SWC conservation investment

	Who primarily participated in construction/maintenance of this ${SWC} on ${plot} ?	How many days in total did { Household decision maker } use in ${swc measures} on ${plot} ?	How many hours per days in total did { Household decision maker } used in ${swc measures} on ${plot} ?	Who primarily participated in application of ${SFC measure} on ${plot} ?	How many days in total did you used in ${SFC measure } on ${plot} ?	How hours per days in total did you used in ${SFC measure } on ${plot } ?	In the season (season 2019A qnd season 2019B), which of the following activities did you personally participat	How many hours per day did you do this {activity} ?	How many days per did you do this {activity}?	How many weeks per season did you do this {activity}?	Who primarily assisted you to do this work in your household?	In the season, did you personally participate in household chores?	How many hours a day did you do this {activity } ?

							e in?						
	12	13	14	15	16	17	18	19	20	21	22	23	24
1													
2													
3													
4													
5													

09. SFC measures:
1**.** DAP
2. Urea
3. NPK
4. Lime
5. Compost & Organic manure
6. Pesticides

1. Touristic sector
2. Extractive sector
3. Agricultural worker
4. Fishing
5. Construction sector
6. Teaching / School work
7. Driver
8. Office worker
9. Army / Police
10. Retail sector
11. NGOs / cooperative
12. Local/central administration
13. Mechanic/garage worker
14. Government. Public Sector
15. Domestic work for another household (e.g. gardener, cleaner, nanny)
16. Other, specify

GD: Time allocated for SWC conservation investment by hired labor

Did you use hired labor for construction/maintenance of this ${SWC} on ${plot} ? No [0] Yes [1]	How many days in total did {Hired labor} use in ${swc measures} on ${plot} ?	How many hours per days in total did {hired labor} used in ${SWC measure} on ${plot} ?	How many {hired labor} did you use for construction /maintenance of this ${SWC measure } on ${plot} ?	How many days in total did {hired labor} use in ${SWC measure} on ${plot} ?	How much in RWF did you pay { hired labor } per day to do this {activity}?	Did you use hired labor for application of ${SFC measure } on ${plot} ? No [0] Yes [1]	How many days in a month did { hired labor } use in applying ${SFC measure } on ${plot} ?	How many hours per days in total did {hired labor } use while applying ${SFC measure } on ${plot} ?	How many {hired labor } did you use to do this work of applying ${SFC measure } on ${plot} ?	How many days in total did {hired labor} use in applying ${SFC measure } on ${plot } ?	How much in RWF per day in total did {hired labor } receive in ${SFC measure } on ${plot} ?	How many hours per day did you do this {activity} ?	How much in RWF did you pay {{hired labor} per day to do this {activity}?
25	**26**	**27**	**28**	**29**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**

PART THREE:

E: SWC investment options: Task Instructions and Example of Best Worst Scaling Choice Sets

Note for Programming:

This section captures the responses from two main decision makers (male and female) in the household. The total sample is 437 households. Eight profiles have been designed with 2 choice sets each.
Profile one & two: was administered to the first bunch of 110 households
Profile three & four: was administered to 111th-220 households
Profile five & six: was administered to 221th-230 households
Profile seven & eight: was administered to 231 households and above

Farm conservation investment has been a serious concern in this Northern Rwanda. Increased soil degradation and high poverty levels are predicted to intensify if no proper conservation practices are made at household plot level. As you probably are aware, SWC investments refer to water erosion control measures and soil fertility control measures. Assume that stakeholders have substantial interest in farm conservation investment but would like to involve you so that you can directly or indirectly bear the costs of investment. I would like to present you different scenarios that describe possible SWC investments to mitigate the above challenges. SWC investments options include your choice to invest in farm consolidated or not; use of soil conservation measures, farm inputs and related costs of conservation. Further, we want you to tell us if your SWC investments options will necessitate sole or joint decision-makingwithin your household, livelihood diversification and improvement in land tenure rights.

In the below tasks, you are required to: 1. Evaluate each of the SWC investment options, 2. Decide which one you prefer the most, 3. Decide which one you prefer the least, 4. Decide which of the remaining two SWC investment options you prefer the most, 5. And decide whether you actually would make the farm conservation investment at all if the only options that you could choose were the ones offered. We ask you four questions about each scenario that reflects the task above. Please insure that you answer EVERY question. Each question requires you to check ONLY ONE BOX, and so be sure that in each scenario you have checked AT LEAST THREE BOXES, but DO NOT CHECK more than FOUR BOXES.

E1_Profile One

Scenario 1				
SWC Investment attributes	**SWC option A**	**SWC option B**	**SWC option C**	**SWC option D**
Land consolidated	Yes	Yes	Yes	Yes
Physical & Structural measures	Grassed ridges farming	Waterways & Anti-Erosion ditches	Hedgerows & Agroforestry	Waterways & Anti-Erosion ditches
Soil fertility management	Fertiliser, Improved seeds & Water use	Fertiliser, Improved seeds & Water use	Participation in WUAs	Participation in WUAs
Cost of farm investment	USD 8.4	USD 7.8	USD 7.8	USD 11.2
Household decision making	Joint male-female	Inclusion of youth decisions	Inclusion of youth decisions	Sole female
Livelihood sources	Own account farming	Off-farming activities	Own account farming	Own account farming
Land tenure rights	Improved land tenure	Current land tenure	Current land tenure	Improved land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0. No)				

Scenario 2

SWC Investment attributes	SWC option A	SWC option B	SWC option C	SWC option D
Land consolidated	No	Yes	No	Yes
Physical & Structural measures	Waterways & Waterways & Anti-Erosion ditches	Grassed ridges farming	Waterways & Anti-Erosion ditches	Waterways & Anti-Erosion ditches
Soil fertility management	Participation in WUAs	Fertiliser, Improved seeds & Water use	Fertilizer & Pesticide	Fertiliser use (org&chem)
Cost of farm investment	USD 3.6	USD 7.8	USD 7.8	USD 7.8
Household decision making	Sole female	Sole female	Sole female	Sole female
Livelihood sources	Own account farming	Own account farming	Off-farming activities	Off-farming activities
Land tenure rights	Improved land tenure	Improved land tenure	Improved land tenure	Current land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0. No)				

E2_Profile Two

Scenario 3				
Land consolidated	No	No	No	No
Physical & Structural measures	Hedgerows & Agroforestry	Hedgerows & Agroforestry	Waterways & Anti-Erosion ditches	Waterways & Anti-Erosion ditches

Soil fertility management	Fertiliser, Improved seeds & Water use	Participation in WUAs	Fertiliser use (org&chem)	Participation in WUAs
Cost of farm investment	USD 8.4	USD 3.6	USD 11.2	USD 8.4
Household decision making	Sole female	Joint male-female	Inclusion of youth decisions	Sole female
Livelihood sources	Own account farming	Off-farming activities	Own account farming	Off-farming activities
Land tenure rights	Improved land tenure	Current land tenure	Current land tenure	Improved land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0. No)				

Scenario 4				
Land consolidated	Yes	No	Yes	No
Physical & Structural measures	Waterways & Anti-Erosion ditches	Waterways & Waterways & Anti-Erosion ditches	Waterways & Waterways & Anti-Erosion ditches	Grassed ridges farming
Soil fertility management	Participation in WUAs	Participation in WUAs	Fertiliser, Improved seeds & Water use	Fertilizer & Pesticide
Cost of farm investment	USD 3.6	USD 11.2	USD 11.2	USD 8.4

Household decision making	Inclusion of youth decisions	Inclusion of youth decisions	Joint male-female	Sole female
Livelihood sources	Own account farming	Own account farming	Own account farming	Own account farming
Land tenure rights	Improved land tenure	Improved land tenure	Current land tenure	Current land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

E3_Profile Three

Scenario 5				
Land consolidated	Yes	Yes	Yes	No
Physical & Structural measures	Grassed ridges farming	Waterways & Waterways & Anti-Erosion ditches	Hedgerows & Agroforestry	Waterways & Anti-Erosion ditches
Soil fertility management	Fertilizer & Pesticide	Fertilizer & Pesticide	Fertiliser use (org&chem)	Participation in WUAs
Cost of farm investment	USD 11.2	USD 7.8	USD 11.2	USD 7.8
Household decision making	Sole female	Inclusion of youth decisions	Joint male-female	Joint male-female
Livelihood sources	Off-farming	Off-farming activities	Off-farming activities	Off-farming

	activities			activities
Land tenure rights	Current land tenure	Improved land tenure	Improved land tenure	Improved land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

Scenario 6				
Land consolidated	Yes	No	Yes	No
Physical & Structural measures	Waterways & Waterways & Anti-Erosion ditches	Hedgerows & Agroforestry	Hedgerows & Agroforestry	Waterways & Anti-Erosion ditches
Soil fertility management	Participation in WUAs	Fertiliser use (org&chem)	Fertiliser, Improved seeds & Water use	Fertilizer & Pesticide
Cost of farm investment	USD 8.4	USD 7.8	USD 11.2	USD 8.4
Household decision making	Joint male-female	Sole female	Sole female	Inclusion of youth decisions
Livelihood sources	Off-farming activities	Own account farming	Off-farming activities	Off-farming activities
Land tenure rights	Improved land tenure	Improved land tenure	Improved land tenure	Improved land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				

Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

E4_Profile Four

Scenario 7				
Land consolidated	Yes	No	No	No
Physical & Structural measures	Waterways & Waterways & Anti-Erosion ditches	Waterways & Waterways & Anti-Erosion ditches	Hedgerows & Agroforestry	Hedgerows & Agroforestry
Soil fertility management	Fertiliser, Improved seeds & Water use	Fertilizer & Pesticide	Fertiliser use (org&chem)	Fertilizer & Pesticide
Cost of farm investment	USD 3.6	USD 11.2	USD 8.4	USD 11.2
Household decision making	Sole female	Sole female	Inclusion of youth decisions	Inclusion of youth decisions
Livelihood sources	Own account farming	Own account farming	Own account farming	Off-farming activities
Land tenure rights	Current land tenure	Improved land tenure	Improved land tenure	Current land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option				

would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

Scenario 8				
Land consolidated	Yes	No	Yes	Yes
Physical & Structural measures	Grassed ridges farming	Grassed ridges farming	Waterways & Anti-Erosion ditches	Grassed ridges farming
Soil fertility management	Fertiliser use (org&chem)	Participation in WUAs	Fertiliser use (org&chem)	Fertiliser use (org&chem)
Cost of farm investment	USD 7.8	USD 7.8	USD 8.4	USD 8.4
Household decision making	Inclusion of youth decisions	Sole female	Joint male-female	Sole female
Livelihood sources	Own account farming	Own account farming	Off-farming activities	Own account farming
Land tenure rights	Improved land tenure	Current land tenure	Current land tenure	Improved land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

E5_Profile Five

Scenario 9				
Land consolidated	No	Yes	No	Yes
Physical & Structural measures	Waterways & Waterways & Anti-Erosion ditches	Hedgerows & Agroforestry	Grassed ridges farming	Grassed ridges farming
Soil fertility management	Fertiliser, Improved seeds & Water use	Fertiliser, Improved seeds & Water use	Fertiliser, Improved seeds & Water use	Participation in WUAs
Cost of farm investment	USD 7.8	USD 3.6	USD 11.2	USD 11.2
Household decision making	Sole female	Inclusion of youth decisions	Inclusion of youth decisions	Joint male-female
Livelihood sources	Off-farming activities	Off-farming activities	Off-farming activities	Off-farming activities
Land tenure rights	Current land tenure	Improved land tenure	Improved land tenure	Current land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

Scenario 10				
Land consolidated	No	No	No	No

Physical & Structural measures	Waterways & Waterways & Anti-Erosion ditches	Hedgerows & Agroforestry	Grassed ridges farming	Grassed ridges farming
Soil fertility management	Fertiliser use (org&chem)	Fertilizer & Pesticide	Fertilizer & Pesticide	Fertiliser use (org&chem)
Cost of farm investment	USD 7.8	USD 3.6	USD 7.8	USD 3.6
Household decision making	Joint male-female	Sole female	Joint male-female	Joint male-female
Livelihood sources	Off-farming activities	Off-farming activities	Own account farming	Off-farming activities
Land tenure rights	Current land tenure	Current land tenure	Current land tenure	Improved land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

E6_Profile Six

Scenario 11				
Land consolidated	Yes	Yes	No	Yes
Physical & Structural measures	Waterways & Waterways & Anti-	Hedgerows & Agroforestry	Grassed ridges	Waterways & Waterways & Anti-

	Erosion ditches		farming	Erosion ditches
Soil fertility management	Fertiliser use (org&chem)	Participation in WUAs	Participation in WUAs	Fertilizer & Pesticide
Cost of farm investment	USD 3.6	USD 8.4	USD 8.4	USD 8.4
Household decision making	Inclusion of youth decisions	Sole female	Inclusion of youth decisions	Sole female
Livelihood sources	Own account farming	Own account farming	Own account farming	Off-farming activities
Land tenure rights	Current land tenure	Current land tenure	Current land tenure	Improved land tenure
Consider these three SWC investment options?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

Scenario 12				
Land consolidated	No	Yes	Yes	Yes
Physical & Structural measures	Hedgerows & Agroforestry	Hedgerows & Agroforestry	Waterways & Anti-Erosion ditches	Waterways & Anti-Erosion ditches
Soil fertility management	Fertiliser, Improved seeds & Water use	Fertiliser use (org&chem)	Fertiliser, Improved seeds &	Fertilizer & Pesticide

			Water use	
Cost of farm investment	USD 7.8	USD 3.6	USD 8.4	USD 3.6
Household decision making	Joint male-female	Sole female	Sole female	Sole female
Livelihood sources	Own account farming	Off-farming activities	Off-farming activities	Own account farming
Land tenure rights	Improved land tenure	Improved land tenure	Current land tenure	Improved land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

E7_Profile Seven

Scenario 13				
Land consolidated	Yes	No	No	No
Physical & Structural measures	Grassed ridges farming	Waterways & Anti-Erosion ditches	Hedgerows & Agroforestry	Waterways & Anti-Erosion ditches
Soil fertility management	Fertilizer & Pesticide	Fertiliser, Improved seeds & Water use	Participation in WUAs	Fertiliser use (org&chem)
Cost of farm investment	USD 3.6	USD 3.6	USD 11.2	USD 3.6
Household decision making	Inclusion of youth	Joint male-	Sole female	Sole female

	decisions	female		
Livelihood sources	Off-farming activities	Own account farming	Off-farming activities	Own account farming
Land tenure rights	Current land tenure	Current land tenure	Current land tenure	Current land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

Scenario 14				
Land consolidated	Yes	No	No	No
Physical & Structural measures	Hedgerows & Agroforestry	Grassed ridges farming	Waterways & Anti-Erosion ditches	Waterways & Waterways & Anti-Erosion ditches
Soil fertility management	Fertilizer & Pesticide	Fertiliser use (org&chem)	Fertiliser, Improved seeds & Water use	Fertiliser, Improved seeds & Water use
Cost of farm investment	USD 7.8	USD 11.2	USD 11.2	USD 8.4
Household decision making	Sole female	Sole female	Sole female	Inclusion of youth decisions
Livelihood sources	Own account farming	Off-farming	Own account farming	Off-farming

		activities		activities
Land tenure rights	Current land tenure	Improved land tenure	Current land tenure	Current land tenure
Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

H8_Profile Eight

Scenario 15				
Land consolidated	Yes	Yes	No	No
Physical & Structural measures	Waterways & Anti-Erosion ditches	Waterways & Waterways & Anti-Erosion ditches	Waterways & Waterways & Anti-Erosion ditches	Grassed ridges farming
Soil fertility management	Fertilizer & Pesticide	Fertiliser use (org&chem)	Fertiliser use (org&chem)	Fertiliser, Improved seeds & Water use
Cost of farm investment	USD 11.2	USD 11.2	USD 8.4	USD 3.6
Household decision making	Joint male-female	Sole female	Sole female	Sole female
Livelihood sources	Own account farming	Own account farming	Off-farming activities	Off-farming activities
Land tenure rights	Improved land tenure	Current land tenure	Current land tenure	Improved land tenure

Consider these three SWC investment option?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				
Consider the remaining box, indicate if you would like not to invest in farm conservation if these were your only SWC options? (1. Yes 0.No)				

Scenario 16				
Land consolidated	No	Yes	Yes	Yes
Physical & Structural measures	Waterways & Waterways & Anti-Erosion ditches	Waterways & Waterways & Anti-Erosion ditches	Grassed ridges farming	Hedgerows & Agroforestry
Soil fertility management	Fertilizer & Pesticide	Participation in WUAs	Participation in WUAs	Fertilizer & Pesticide
Cost of farm investment	USD 3.6	USD 7.8	USD 3.6	USD 8.4
Household decision making	Joint male-female	Sole female	Sole female	Joint male-female
Livelihood sources	Own account farming	Off-farming activities	Off-farming activities	Own account farming
Land tenure rights	Improved land tenure	Improved land tenure	Current land tenure	Current land tenure
Consider these three SWC investment options?				
Which SWC option would you prefer MOST?				
Which SWC option would you prefer LEAST?				
Which one of the two remaining SWC option would you prefer MOST?				

Appendix C: Descriptive statistics of dependent and control variables or covariates

Variables	Variable description	Mean	SD
Dependent variable			
HH_INCOME	Average annual household income (USD) by all members in a household	1340.02	60.97
Endogenous variable			
SWC_FINVEST	Is 1 if the HH pays labor to finance SWC, 0 otherwise	0.37	0.02
Socio-economic characteristics			
Gender	Gender of respondents (Female=0 & Male=1)	0.39	0.02
Age	Average age of the HH head (in years)	45.18	0.57
Household size	Average family size (numbers)	4.88	0.13
Education (years)	Years of formal education (Primary one =1 to university=15)	3.79	0.17
Off-farm employment	Off-farm employment (No=0 &yes=1)	0.27	0.03
Ownership of HH asset (log)	Household asset index (HAI)	1.22	0.03
Livestock ownership	Number of livestock owned by the HH (in TLU)	0.98	0.06
Institutional factors			
Access to agric-extension and communication services	% Category of AAECS [1=Limited (51.6%) to 3=Diverse (40.15%)]		
SWC Program	If HH received SWC Program (No=0; Yes=1)	0.09	0.01
Gender program (GPI)	If HH received gender program (No=0; Yes=1)	0.1	0.01
Access to Input market (IM)	Walking distance to nearest input market (Mn)	27.02	1.76
Access to output market (OM)	Walking distance to nearest output market (Mn)	31.55	1.69
Proximity to town (PT)	Proximity to town (walking minutes)	110.18	6.58
Road status (%RS)	1=Very bad (17.77%); 2=Bad (20.85%); 3=Moderately good (19.19%); 4=Good (26.30%); 5= Very good (15.88%)		
Plot characteristics			

Number of plots	Number of plots cultivated by the household	2.52	0.07
Plot distance	Average walking distance home-plot (Mn)	21.02	0.85
Farm size	Average cultivated farm size (Ha)	1.61	1.22
Plot location	1= Hillside (73.74%); 2=Top of the hill (13.28%); 3=Valley (12.98%)		
Crop commercialization			
Maize	Maize commercial production (No=0; Yes=1)	0.64	0.02
Irish potato	Potatoes commercial production (No=0; Yes=1)	0.57	0.02
Beans	Beans commercial production (No=0; Yes=1)	0.78	0.02
Cassava	Cassava commercial production (No=0; Yes=1)	0.052	0.01
Coffee	Coffee commercial production (No=0; Yes=1)	0.094	0.01

Appendix D: OLS results in comparison to the results of ISURE (in natural log)

Variables	**Invisible SWC**		**SC practices**		**SFM practices**		**Integrated SM & WC**		**FISWC**	
log_NON_INVESTSWC	**Coeff.**	**St. Err**	**Coeff.**	**St. Err**	**Coeff.**	**St. Err**	**Coeff.**	**St. Err**	**Coeff.**	**St. Err**
Autonomy in production	-7.11***	0.75	6.38***	2.13	9.28***	2.28	1.63	2.17	1.63	2.17
Input in productive decisions	2.11***	0.29	-2.14***	0.81	-3.07***	0.87	-0.89	0.78	-0.896	0.78
Access to and decisions on financial services	0.26***	0.11	0.32	0.31	-0.38	0.33	0.17	0.26	0.17	0.26
Control over use of income	0.19	0.15	-0.39	0.43	0.02	0.46	0.16	0.38	0.16	0.38
Work balance (Workload)	0.002***	0.01	-0.004***	0.001	-0.004***	0.001	-0.00	0.0011	-0.001	0.001
Group membership	0.01	0.10	0.144	0.28	-0.01641	0.30	-0.008	0.25	-0.008	0.253
Membership in influential groups	0.08	0.03	-0.15*	0.081	-0.49***	0.08	-0.15**	0.07	-0.16**	0.07
Age	-0.01*	0.01	-0.06***	0.02	-0.08***	0.01	-0.11***	0.01	-0.11***	0.01
Education level	0.05***	0.02	-0.01	0.04	0.008	0.05	-0.03	0.04	-0.03	0.04
Main occupation	-1.31***	0.11	-0.03	0.32	2.51***	0.34	-0.25	0.35	-0.25	0.35
Input-market	0.0***	0.01	-0.05***	0.01	-0.02**	0.01	-0.00675	0.008515	-0.006	0.008
Output-market	-0.02***	0.01	-0.05***	0.01	-0.027**	0.01	-0.02405	0.010	-0.024	0.01
Plot distance	0.001	0.01	0.01***	0.00	0.02***	0.03	0.014312	0.002153	0.014312	0.002153
_cons	3.07***	0.57	14.92***	1.62	14.63***	1.73	14.93786	1.350781	14.93786	1.350781

Appendix E: Stata commands used in the analysis

***** Runnuing the ISURE**

sureg (log_NON_INVESTSWC i.empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance), small dfk

sureg (log_TOTAL_SWCINVESTMENTS i. empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance), small dfk

sureg (log_OVERAL_TIME_SFC i.empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance), small dfk

sureg (log_OVERAL_SWCINVESTMENTS i.empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance), small dfk

sureg (log_paid_SWFC i.empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance), small dfk.

*****Running the OLS model**

reg log_NON_INVESTSWC i.empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance

reg log_TOTAL_SWCINVESTMENTS i. empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance

reg log_OVERAL_TIME_SFC i.empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance

reg log_OVERAL_SWCINVESTMENTS i.empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance

reg log_paid_SWFC i.empowerscore age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance.

Runniung ISURE tests

global y1list NON_INVESTSWC

global y2list OVERAL_SWCINVESTMENTS

global y3list SWC_FInvestments

global x1list feelinputdecagr_sum ownership_asset_sum transfer_asset_sum accesdecision_credit_sum group_membership_sum incomedec_sum speaking_public_sum primary_work_sum secondary_work_sum raiprod_any age b08_1_Educ b09_1 bj8a_Input_market plot_distance

global x2list feelinputdecagr_sum ownership_asset_sum transfer_asset_sum accesdecision_credit_sum group_membership_sum incomedec_sum speaking_public_sum

primary_work_sum secondary_work_sum raiprod_any age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market plot_distance

global x3list feelinputdecagr_sum ownership_asset_sum transfer_asset_sum accesdecision_credit_sum group_membership_sum incomedec_sum speaking_public_sum primary_work_sum secondary_work_sum raiprod_any age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance)

sureg ($y1list $x1list) ($y2list $x2list), corr

sureg ($y2list $x2list) (log_TOTAL_SWCINVESTMENTS OVERAL_SWCINVESTMENTShat feelinputdecagr_sum ownership_asset_sum transfer_asset_sum accesdecision_credit_sum group_membership_sum incomedec_sum speaking_public_sum primary_work_sum secondary_work_sum raiprod_any age b08_1_Educ b09_1 bj8a_Input_market bj8b_Output_market bj8d_Proximity_town plot_distance), corr

Test for multicollinearity with estat vif command in Stata and correct multicollinearity problem

estat vif ////interpretation of the VIF results

corrr /////interpretation of the corr results and reasons for joint effects.

***Performing a tw0-stage least squares to remove endogeneity (2SLS--)**

regress HH_INCOME_USD sex age hhsize_AEq b08_1_Educ b09_1 i.b05_1 ca01_1 ca01_2 ca01_3 ca01_8 ca01_10 dbx_asset_index TLU bi1 i.SN_category bj8a_Input_market bj8b_Output_market bj8d_Proximity_town i.bj9_Road_status farm_size TOTAL_SFC_HHTIME TOTAL_SFC_PAIDTIME OVERAL_SWCINVESTMENTS

ivregress 2sls HH_INCOME_USD (OVERAL_SWCINVESTMENTS= plot_avdistance i.g1_1 g1_41) sex age hhsize_AEq b08_1_Educ b09_1 i.b05_1 ca01_1 ca01_2 ca01_3 ca01_8 ca01_10 dbx_asset_index TLU bi1 i.SN_category bj8a_Input_market bj8b_Output_market bj8d_Proximity_town i.bj9_Road_status farm_size TOTAL_SFC_HHTIME TOTAL_SFC_PAIDTIME TOTAL_SWCINVESTMENTS

predict OVERAL_SWCINVESTMENTShat

regress HH_INCOME_USD OVERAL_SWCINVESTMENTShat sex age hhsize_AEq b08_1_Educ b09_1 i.b05_1 ca01_1 ca01_2 ca01_3 ca01_8 ca01_10 dbx_asset_index TLU bi1 i.SN_category bj8a_Input_market bj8b_Output_market bj8d_Proximity_town i.bj9_Road_status farm_size TOTAL_SFC_HHTIME TOTAL_SFC_PAIDTIME TOTAL_SWCINVESTMENTS

qreg HH_INCOME_USD OVERAL_SWCINVESTMENTShat sex age hhsize_AEq b08_1_Educ b09_1 i.b05_1 ca01_1 ca01_2 ca01_3 ca01_8 ca01_10 dbx_asset_index TLU bi1 i.SN_category bj8a_Input_market bj8b_Output_market bj8d_Proximity_town i.bj9_Road_status farm_size TOTAL_SFC_HHTIME TOTAL_SFC_PAIDTIME TOTAL_SWCINVESTMENTS, quantile(.25) vce(iid, kernel(parzen) chamberlain)

qreg HH_INCOME_USD OVERAL_SWCINVESTMENTShat sex age hhsize_AEq b08_1_Educ b09_1 i.b05_1 ca01_1 ca01_2 ca01_3 ca01_8 ca01_10 dbx_asset_index TLU bi1 i.SN_category bj8a_Input_market bj8b_Output_market bj8d_Proximity_town i.bj9_Road_status farm_size

TOTAL_SFC_HHTIME TOTAL_SFC_PAIDTIME TOTAL_SWCINVESTMENTS, quantile(.75) vce(iid, kernel(parzen) chamberlain)

qreg HH_INCOME_USD OVERAL_SWCINVESTMENTShat sex age hhsize_AEq b08_1_Educ b09_1 i.b05_1 ca01_1 ca01_2 ca01_3 ca01_8 ca01_10 dbx_asset_index TLU bi1 i.SN_category bj8a_Input_market bj8b_Output_market bj8d_Proximity_town i.bj9_Road_status farm_size TOTAL_SFC_HHTIME TOTAL_SFC_PAIDTIME TOTAL_SWCINVESTMENTS, quantile(.90) vce(iid, kernel(parzen) chamberlain)

Appendix F: Research permit

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY (NCST)
Grand Pension Plaza, 13th Floor, KN 2 Roundabout, Kigali
PO Box: 2285 Kigali – Rwanda
E-MAIL: info@ncst.gov.rw ,WEBSITE: www.ncst.gov.rw

PERMISSION TO CONDUCT RESEARCH IN RWANDA

N° NCST/482/150/2019

I, the undersigned, hereby grant the researcher (s) in Section I permission to conduct research in Rwanda. This permission only covers research activities related to the provided research title during the specified period and at specified location (s) in Section II of this form.

Section I: Personal Information

1. Family Name: Idephonse Other Names: Musafili
2. Academic Qualification (Highest degree): MS, MA
3. Home Institution: Egerton University Occupation: PhD S
4. Phone Number (in Rwanda): 0788624422
5. Email: musafili@gmail.com
6. Primary Research Supervisor:
   a. Names: Dr. Eliud Abuheli Birachi
   b. Institution: CIAT Occupation: Country Director
   c. Phone Number: +250 783808149
   d. Email: e.birachi@cgiar.org
7. Research Collaborators:

	Names	Institution
1	Justin Dodd Mullikin	Rutgers University, US
2	Christine Bigler	University of Bern, Switzerland
3	Marie Louise Matthys	University of Bern, Switzerland
4	Illien Patrick	University of Bern, Switzerland

Appendix G: Photo from Research work

Appendix H: Published papers

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EFFECTS OF SOIL AND WATER CONSERVATION INVESTMENT ON HOUSEHOLD INCOME IN THE VOLCANOES NATIONAL PARK OF RWANDA: AN INSTRUMENTAL VARIABLE QUANTILE APPROACH

Ildephonse Musafili[1]✉, Oscar Ingasia Ayuya[1], Eliud Abucheli Birachi[2]

[1]Egerton University, Kenya
[2]International Center for Tropical Agriculture (CIAT), Rwanda

Abstract. Soil and water conservation (SWC) technologies contribute to sustainable agriculture and rural poverty reduction. Yet, the relationship between farm household income and SWC investment is not well-understood in Rwanda. This study aims to assess the effects of investing in SWC on household income and improve the knowledge of how various classes of smallholders can benefit from such an investment at a farm level. The study used survey data from 422 farming households in northern Rwanda's Burera, Gakenke and Musanze districts. Descriptive analysis was employed to determine levels of use of SWC and SF measures. Quantile estimation classified three classes of farming households: the poor, middle-income earners and the rich. Instrumental variable quantile regression was adopted to assess heterogeneous effects of financing SWC investment. The results revealed that the extent of using SWC and SF measures is generally low. Agriculture income and off-farm (casual) wages had the largest income shares among the poor and middle-income earners for the poor and close income gaps among the three farming classes. This finding suggests the need to introduce saving and lending innovations in SWC that link farm activities to non-farm opportunities.

Keywords: soil and water conservation investment, income effects, instrumental variable quantile, farming household, Volcanoes National Park

INTRODUCTION

Soil and water conservation (SWC) technologies contribute to sustainable agriculture and rural poverty reduction for smallholder households. Empirical studies point out that productivity gains from SWC can be

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Dynamics of Gender Preferences for Farm Investment Strategies in Rwanda: A Best-worst Scaling Experiment

Ildephonse Musafili[1] ✉ **Oscar Ingasia Ayuya**[2] **and Eliud Abucheli Birachi**[3]
[12]*Department of Agricultural Economics and Agribusiness Management, Egerton University, Kenya*
[3]*International Center for Tropical Agriculture (CIAT), Rwanda*
✉ **Corresponding Author:** Ildephonse Musafili, **E-mail**: musafili@gmail.com

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Gender preferences, farm investment strategies, Best-worst experiment, Multinomial logit, Rwanda

ABSTRACT

Gender gaps affect how women and men access, participate and benefit from the adoption of various farm investment strategies, environmental conservation and sustainable development. Production, conservation, and livelihood strategies are motivated by land and household decision-making dynamics. Understanding gender preference dynamics on investment fills a gap in the gendered division of labor, market participation and agricultural transformation. The study adopted a household survey on 653 male and female respondents in the Burera, Gakenke and Musanze districts of Northern Rwanda. Analysis revealed three farm investment strategies in relation to the relative importance for the agricultural transformation process: the best (>85%), intermediate (between 60% and 85%), and low (<60%). Male and females had varied preferences (positive or negative) for the strategies. Females preferred livelihood strategies that combined on-farm and off-farm sources. The study recommends the adoption of diversified production and livelihood strategies to improve farm investment and market access. Land systems should consider youth inclusion as a dynamic factor in household decision making, women empowerment and agricultural transformation.