Participatory Agent-Based Modelling for Sustainable Watershed Management in the Central Rift Valley of Ethiopia

Samuel Assefa Heban

Propositions

1. The national Campaign-Based Watershed Management program of Ethiopia will not produce sustainable outcomes as long as the government applies a rather top-down intervention approach.
   (this thesis)

2. Community empowerment is essential to any intervention that aims to scale-up soil and water conservation in Ethiopia.
   (this thesis)

3. Social stratification persists because it is supported by patterns of belief that justify inequality among people.

4. Creating unrealistic expectation among citizens is certain to lead to demotivation and even resentment.

5. Human behavior is much more influenced by childhood socialization, than by formal trainings.

6. One of the limitations of democracy is that all citizens have equal vote to elect their rulers.

Propositions belonging to the thesis entitled,

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Samuel Assefa Heban
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Dedicated to my late father, Assefa Heban

1. General introduction

1.1 Land degradation in the Central Rift Valley of Ethiopia

Agriculture is the backbone of the Ethiopian economy, accounting for about 42% of its Gross Domestic Product and 90% of its export revenues, while it constitutes a main source of livelihood for about 85% of the population (CSA, 2015). However, land degradation has been a main obstacle for sustained agricultural production and productivity in the country (Rahmato and Assefa, 2006; Miheretu and Yimer, 2017). Soil erosion and soil fertility depletion are forms of land degradation reducing the capacity of land resources to perform essential functions such as the production of food (Amsalu and de Graaff, 2007; Hurni et al., 2010). Soil erosion by water is one of the most critical processes affecting the quality of soil, land, and water resources, upon which farmers directly depend for survival (Amsalu and de Graaff, 2007; Atnafe et al., 2015). For instance, the average soil loss by sheet and rill erosion is estimated at 29.9 t ha^{-1} yr^{-1} at the national level (Haregeweyn et al., 2015), higher than the criterion for hotspot areas which is set at a soil loss of 20 t ha^{-1} yr^{-1} in the country (Meshesha et al., 2012). Soil fertility declines associated with the removal of topsoil by water erosion contributes to lower crop yield, food insecurity, and rural poverty (Sonneveld and Keyzer, 2003; Agegnehu and Amede, 2017).

Land degradation has been particularly significant in the Central Rift Valley (CRV) of Ethiopia, with for instance an estimated soil loss amounting to 56 t ha^{-1} in 2006 (Meshesha et al., 2012). The vulnerability of this semiarid to arid region to land degradation is attributed to adverse changes in land use in a sensitive natural environment characterised by sloping terrain and heavy rainfall (Ayenew, 2004; Fenta et al., 2017; Berihun et al., 2019). For instance, Meshesha et al. (2010) reported that from 1973 to 2006 forest and woodland decreased by 66% and 69% respectively; while degraded land increased by 200%. Severe land degradation has made large areas unsuitable for crop production, decreased agricultural productivity, worsened food insecurity, and increased poverty throughout the CRV (Meshesha et al., 2010). The observed soil erosion rates in the CRV require urgent measures to reverse the problem of land degradation and improve ecosystem services for better agricultural production and food security.

1.2 Watershed management in Ethiopia

Land degradation has been tackled by successive governments of Ethiopia since the 1970s, through efforts including the promotion of Soil and Water Conservation (SWC) structures, soil fertility management, controlled-grazing, afforestation, and area closures (Gebremedhin, 1998; Adimassu et al., 2017). Following the 1972/1973 drought and famine in the food insecure areas of the country, interventions began through a food-for-work program during the Imperial Regime (1930-1974) (Osman and Sauerborn, 2001; Desta et al., 2005). The Derg regime (1974-1991) continued with the food-for-work approach in localities where aid agencies supported the program and introduced an intervention that requires farmers to contribute free labor for campaign works on communal land, particularly after the next 1984/1985 droughts and famine in Ethiopia (Dejene, 2003; Bewket, 2007). However, these efforts did not curb the problem in a meaningful and sustainable manner, mainly due to the governments' top-down approach and emphasis on physical structures (Bewket and Sterk, 2002; Zeleke, 2006), as well as the failure to consider variations in agro-ecological conditions, including indigenous land management practices (Amsalu and De Graaff, 2006; Berihun et al., 2019).

The current government (after 1991) further promoted watershed management interventions to restore natural resources. In order to align these efforts, guidelines for "participatory watershed management" interventions were introduced (Desta et al., 2005; MoARD, 2008). As a result, different "participatory watershed management" interventions have been carried out in Ethiopia. Most notable were sustainable land management activities implemented as part of Ethiopia's agricultural extension programs for individual farm households between 1995 and 2009 (Bewket, 2007). Similar to the interventions of the Derg regime, the current interventions take two forms: project-based and non-project based. Project-based interventions are usually carried out with the provision of incentives to encourage farmers' participation. Prominent projects in this category include "Managing Environmental Resources to Enable Transition (MERET)", the "Productive Safety Net Program (PSNP)", and the "Sustainable Land Management Program (SLM)" (MoARD, 2008). The non-project based intervention, hereafter "Campaign-Based Watershed Management (CBWM)" program has been carried out through community mass mobilization since 2011/12.

1.3 The Campaign-Based Watershed Management program in Ethiopia

The CBWM program requires all resident adult farmers to collectively work on one or more micro-watersheds (comprising communal land, private farmland, or both) for 30 to 40 days every year in their respective *Kebeles*[1] (villages) (Danano, 2010). The program activities are carried out without incentives and are coordinated by government actors at the Regional, Zonal, District, and *Kebele* levels. The most important actors for mobilization of farmers during campaign works are *Kebele* administrators, leaders of development teams (groups of

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[1] *Kebele* (village) is the smallest administrative unit in Ethiopia, similar to a ward

local networks), and leaders of the local networks (groups of five households) (Wolancho, 2015). Local supervisors and extension workers are responsible for planning or channeling government plans to farmers and give technical support during campaign works (FDRE, 2016).

The main conservation measures implemented during campaign works include hillside terraces, soil and stone bunds, check-dams, cut-off drains, waterways, tree planting, area enclosures and in-situ moisture conservation practices. The program has been considered successful in terms of farmers' labor contribution for campaign works and area of land covered with SWC structures (ORAB, 2014; Haregeweyn et al., 2015).

1.4 Problem statement

The sustainability of the ongoing CBWM program requires active participation of key actors in the planning and implementation of the program, which is essential to create a sense of ownership and ensure sustainable land management (Kessler, 2007; Snyder et al., 2014). However, recent studies show that the program mainly follows a top-down approach, with limited participation of farmers at the planning stage (Weldemariam et al., 2013; Snyder et al., 2014). As a result, farmers' needs, aspirations and their indigenous knowledge and practices are hardly considered in the program (Mulema et al., 2017), leading to farmers' limited genuine participation in campaign works (Wolka, 2014; Wolancho, 2015) and limited maintenance of the constructed SWC structures (Snyder et al., 2014).

Hence, it is essential to conduct more research that enhances our understanding of the CBWM program and to develop alternative strategies that ensure more sustainable impact. Participatory Agent-Based Modelling has been used as a research approach to simulate such complex systems and explore alternative watershed management strategies (Valbuena et al., 2008; An, 2012).

However, in order to develop a Participatory Agent-Based Modelling approach it is first of all essential to identify and analyze factors that affect actors' decisions in the CBWM program. Several studies show that farmers' intrinsic motivation and genuine participation are key to enhance their sense of ownership for sustainable land management (Kessler, 2007; Snyder et al., 2014; Kessler et al., 2016). It is therefore crucial to determine factors that influence farmers' participation in the CBWM program, which serve as input to represent micro-level decisions of farmers, their attributes, and interactions in the Agent-Based Model (ABM). However, studies on watershed management in Ethiopia pay little attention to participation, but rather focus on econometric analysis of adoption of SWC structures on private farmlands (e.g. Belay and Bewket, 2013; Adimassu, et al., 2013; Kacho and Asfaw, 2014; Tesfaye et al., 2014). This is the reason that this study will gather first-hand information to explain contextual factors that influence farmers' decisions to participate in the planning, implementation, and post-implementation stages of the CBWM program.

In addition, data on the outcomes of the CBWM program enable to link micro-level decisions of the actors with the resultant macro-level patterns or emergent conditions in the ABM. Particularly, assessing the effects that the outcomes of the program have on the willingness of farmers to participate in upcoming program activities is an important indicator of sustainability of the program. So far, empirical evidences on outcomes of watershed management in Ethiopia mainly focus on project-based interventions (e.g. Mazengia and Mowo, 2013; AgWater Solutions, 2012; Adimassu, et al., 2013; Tongul and Hobson, 2013), paying little attention to activities that are carried out through mass mobilization of farmers, including the CBWM program. This study therefore focuses on the outcomes of the CBWM program and assesses its effect on farmers' willingness to participate in the upcoming program activities.

Furthermore, Role-playing Games (RPGs) are often used to explore actors' decision-making (Pak and Brieva, 2010; Edwards et al., 2019) and facilitate learning and collective decision making (Campo et al., 2009; García-Barrios et al., 2011; Moreau et al., 2019). This is also an innovative option to further explore farmers' decision-making in the context of the CBWM program, and facilitate mutual learning and collective decisions among actors. Such incremental analysis of the CBWM program is an important step to develop a more complex ABM to explore scenarios or strategies that enhance the outcomes and sustainability of the program (Pak and Brieva, 2010; Fleskens et al., 2014).

1.5 Objectives of the study

The general objective of this study is to explore strategies that enhance the sustainability of the Campaign-Based Watershed Management program in the Boset District of Ethiopia. The specific objectives are to:

RO1:Explain factors that affect farmers' decisions to participate at the planning, implementation, and post-implementation stages of the program;
RO2:Assess outcomes of the program and its effect on the willingness of farmers to participate in the upcoming program activities;
RO3:Develop a Role-Playing Game to explore decision-making and mutual learning among actors in the program; and

RO4:Develop an Agent-Based Model and conduct scenario analysis to identify strategies that enhance the outcomes of the program.

1.6 Material and methods

1.6.1 Description of the study area

The study was conducted in the CRV of Ethiopia in Oromia Regional State, where land degradation seriously affects agricultural production (Adimassu et al., 2012). The eastern and western highlands are the main boundaries of the CRV and the elevation ranges approximately from 1,600 m above sea level in the valley to over 3,000 m on the escarpments. The average annual temperature is relatively constant throughout the year, but ranges between 25-30 °C for the tropical and 15-20 °C for the subtropical zones (BDFEDO, 2012).

This study focused on Boset District to narrow down the scope of the study in the face of resource and time constraints, and unavailability of similar studies in the area. The study focused on administrative boundaries (instead of hydrological boundaries), because the CBWM program is planned and implemented according to the administrative boundaries. CSA (2013) estimated the District's total population to be 174,659 in 2013, out of which 78.7% (137,517) lives in rural areas.

Concerning CBWM program performance, outputs in terms of quantity and quality as well as farmers' ownership of activities implemented between 2011/12 and 2015/16, out of the 33 rural *Kebeles* in the Boset District 10 are considered successful, 14 moderate, and nine weak (BDAO, 2015). For the purpose of this study, three adjacent *Kebeles* were purposively selected: Ararso-Bero, Sara-Areda, and Qachachule-Guja (Figure 1.1). The main criterion of selection was their relative performance in CBWM activities. According to BDAO (2015), Ararso-Bero was the best performing *Kebele* in the District, while performances in Sara-Areda and Qachachule-Guja *Kebeles* were moderately successful and weak, respectively. This gives an opportunity to analyze processes and factors that contribute to variation in achievement across the *Kebeles*. The 3 study *Kebeles* together include a total of 4,068 households and cover a total area of 10,669 ha (BDAO, 2015).

1.6.2 Methods

The study followed a Participatory Agent-Based Modelling approach. It began with an in-depth analysis of the CBWM program, followed by the construction of an ABM and the exploration of scenarios. To examine the CBWM program, mixed research methods were used. First, key informant interviews were conducted with experts in the Oromia Region Natural Resource Conservation and Protection Unit, experts in Boset District Natural Resource Management Department, a local supervisor, *Kebele* administrators, extension workers, leaders of development teams, and village elders. This was followed by individual case studies with farmers. Both key informant interviews and individual case studies were conducted in August 2016 to collect predominantly qualitative data. This data was used as an input to design a household survey, which was conducted in January and February 2017. Data obtained through the key informant interviews, individual case studies, and household survey were employed to design a RPG, which was conducted with the participation of 36 actors in January 2018. The key informant interviews, individual case studies, household survey, and the RPG were used as an input to design an ABM.

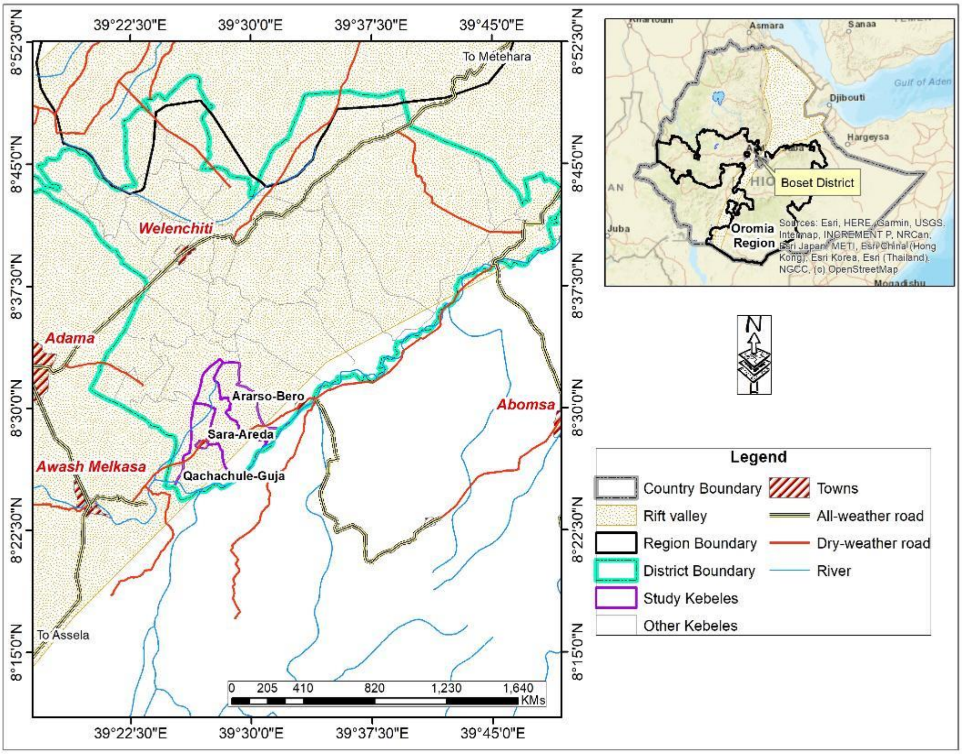

Figure 1.1 Map of the study area: Ethiopia, Rift Valley, Bosat District, and study Kebeles.

For RO1, which assesses farmers' level of participation in the CBWM program and factors that determine their participation, key informant interviews, individual case studies, and a household survey were used. Descriptive statistics, one-way Analysis of Variance (ANOVA), and a Negative Binomial Regression Model (Maximum Likelihood Estimation - MLE) were employed to analyze data obtained through the household survey. Data obtained from the key informant interviews and individual case studies were analyzed following qualitative procedures, i.e. by organizing data into themes or categories following interview guides. Finally, the quantitative and qualitative data were integrated to substantiate findings and understand the program more comprehensively.

To assess the outcomes of the CBWM program and its effect on the willingness of farmers to participate in upcoming program activities (RO2), key informant interviews and a household survey were used. Google Earth Engine was employed to make some quantitative estimates of outcomes (area of micro-watersheds, lengths of SWC structures, vegetation cover). Descriptive statistics, one-way ANOVA and factor analysis were used to analyze quantitative data. This data was substantiated by qualitative data obtained through key informant interviews. Finally, Spearman's partial correlation coefficients were used to determine the influence of farmers' perceived outcomes of the CBWM program on their willingness to participate in the program.

A RPG was developed to further explore decision-making and facilitate mutual learning among actors in the program (RO3). The game requires farmers to choose between advancing their individual and collective interests. It aims at assessing farmers' decision-making, and facilitating discussions and mutual learning among actors to make collective decisions on alternative watershed management strategies. In this regard, the game was an important platform to refine our understanding of the CBWM and identify possible solutions to be used as an input to explore scenarios using an ABM. In order to collect relevant data during the game sessions, observation of farmers' behavior and group discussions were used. Data collected from the game sessions were analyzed using descriptive statistics and qualitative procedures.

For RO4, dealing with developing an ABM and exploring scenarios, empirical data collected for RO1, RO2, and RO3 were used as an input. The development of the model was underpinned by an in-depth analysis of attributes, decisions and interactions among actors (input from RO1) and outcomes of the CBWM program (input from RO2). The first conceptual model was prepared using Unified Modelling Language (UML). Next, the RPG was used to validate the conceptual model and further explore actors' behavior. The concceptual model was then described using the "Overview, Design concepts, and Details" (ODD) protocol (Grimm et al., 2010). Finally, the conceptual model was used to develop a computer model using the NetLogo v6.2 platform. The model results were presented using descriptive statistics.

1.7 Thesis outline

This thesis encompasses six chapters. Chapter 1, this chapter, provides the general introduction of the thesis focusing on a brief overview of the problem of watershed degradation and watershed management strategies, research problem and objectives, and methods used to address the objectives. Chapter 2 analyzes farmers' level of participation in the CBWM program and factors that influence their participation. Chapter 3 evaluates outcomes of the CBWM program and how this influences the willingness of farmers to participate in the program. Chapter 4 briefly describes the RPG and its implementation to explore decision-making and mutual learning among actors in the program. Chapter 5 provides a description of the ABM and scenario analysis to identify promising watershed management strategies to enhance the outcomes of the program. The final Chapter 6 discusses the major findings of the thesis, main conclusions drawn from the findings, the contributions of the findings to science, and issues for future research.

2. Factors affecting farmers' decision to participate in campaign-based watershed management program in Boset District, Ethiopia

The Campaign-Based Watershed Management (CBWM) program of the Ethiopian government relies on mass mobilization of farmers to respond to the problem of watershed degradation, particularly soil fertility depletion and water erosion. This study explains factors that determine the farmers' level of participation in the program, using key informant interviews, individual case studies and a household survey conducted between August 2016 and February 2017. The results of the study show that the farmers' level of participation in the CBWM program was quite low (53.0%). Compared to the implementation and post-implementation stages, the level of participation was lowest at the planning stage of the program. Three key factors influenced the farmers' level of participation in the program: location or proximity of farmers to the micro-watersheds, the commitment of local leaders, and awareness and motivation of farmers. This suggests the need to (1) focus on smaller watersheds to minimize the effect of farmers' distance from micro-watersheds, and to enhance their sense of ownership, (2) enhance farmers' awareness and motivation through capacity building, (3) include local livelihood opportunities to apply a more integrated approach, and (4) enhance the performance/commitment of local leaders. However, given that the effect of these factors varies across the studied villages and stages of the program, a more bottom-up planning approach that considers socio-economic and biophysical contexts of each village should be introduced. This can be achieved by capacity building of local actors so that they can plan and implement the program in their respective villages. Such an approach will enhance the farmers' level of participation and ownership of the program.

Based on:

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2.1 Introduction

Watershed management has been promoted in developing countries in the 1970s and 1980s in National and Regional programs to ensure conservation of soil and water resources (Darghouth et al., 2008). However, many programs have performed poorly because they failed to take into account the needs, constraints, and knowledge of local people (Johnson et al., 2002). In Ethiopia, successive governments of the country have introduced land management practices since the 1970s to respond to land degradation, particularly soil fertility depletion and water erosion (Osman and Sauerborn, 2001; Amsalu and de Graaff, 2007). Although the mechanisms and motives differ, engaging farmers has remained central to watershed management initiatives since the first donor-sponsored interventions during the Imperial Regime (1930-1974). Following the 1972/73 drought and famine in the food insecure areas of the country, the government introduced food-for-work programs to address the problem of food shortage as well as to ensure the participation of farmers in environmental rehabilitation activities (Osman and Sauerborn, 2001; Bewket, 2003; Desta et al., 2005). The main objective of the program was to construct Soil and Water Conservation (SWC) structures and carry out afforestation. The planning of the program followed a top-down approach and the participation of farmers was assumed to be achieved through their labor contribution in exchange for food items (Gebremedhin and Swinton, 2003).

During the *Derg* government (1974-1991), particularly after the 1984/85 droughts and famine, natural resource conservation and afforestation activities were carried out by the government itself as well as with the assistance of aid agencies. In the former case, farmers were obliged to contribute free labor through campaign works. Soil and stone bunds, hillside terraces, and afforestation/closures were the main conservation technologies implemented during such campaigns (Wood and Stahl, 1990). However, in areas where the aid agencies supported the program, the activities were mainly carried out through food-for-work incentives (Shiferaw and Rao, 2006). The main objective of these projects was to cover the barren hillsides with vegetation and to reduce the level of erosion on agricultural fields through on-farm structures, particularly soil bunds (WFP, 1990). However, after the fall of the *Derg* regime, both initiatives were discontinued, and farmers demolished most of the SWC structures that were constructed on their cultivated fields, resorting to their traditional land use practices (Bewket, 2003).

Also, the current government has put in place numerous policies, programs and initiatives for the conservation and restoration of natural resources through watershed management (MoNRDaEP, 1994; MoFED, 2003; MoRD, 2003; MoARD, 2008). Most recently, this is being promoted as the “climate change resilience and adaptation strategy” (ENAPA, 2007; FDRE, 2012). In order to align watershed management efforts, guidelines for "participatory watershed management" interventions were introduced (Desta et al., 2005; MoARD, 2008). Similar to the *Derg* regime's interventions, current watershed management interventions can be categorized into project-based (carried out through food-for-work payments or other incentives) and non-project based interventions (carried out through campaign works). Project-based interventions are generally limited in coverage but require huge investments. The non-project or Campaign-based Watershed Management (CBWM) interventions are carried out through community mass mobilization. The main guiding principle of the CBWM program is community-based participatory watershed development, which emphasizes the genuine participation of farmers in initiatives that pursue both natural resource development and livelihood improvement goals. The CBWM program requires all resident adults to carry out watershed management activities for 30 to 40 days per year, without any form of remuneration and is coordinated by existing government structures and actors at Regional, Zonal, District and *Kebele* levels. Key actors for implementation are *Kebele* administrators, leaders of development teams, and leaders of the local networks (groups of five households), who are all responsible for developing and administering internal regulations that enforce, encourage, and control participants in the campaign works (Wolancho, 2015). Furthermore, local supervisors, whose responsibility is to oversee extension workers, are key actors to channel government plans to farmers. In the post-implementation stage, micro-watersheds[2] on communal land are handed over to associations, who are supposed to maintain, protect, and use the micro-watersheds, while those on private farmlands are handed over to individual owners.

The government has been promoting the CBWM program since 2011/12. It claims that between 2011/12 and 2014/15, SWC activities were carried out on 16.3 million ha of land in the country (ORAB, 2014). The sustainability of such programs largely depends on farmers' intrinsic motivation and genuine participation (Kessler, 2007; Snyder et al., 2014; Kessler et al., 2016). However, data concerning the participation of farmers in the CBWM program are hardly available as existing studies generally focus on individual farmers' plots and adoption of SWC structures (Belay and Bewket, 2013; Tesfaye et al., 2014; Adimassu et al., 2016; Abi et al., 2018a).

Data obtained from recent empirical evidence, however, show that although farmers' labor contribution for communal land management has been regarded as a great achievement of the CBWM program, proper protection and maintenance of SWC structures is often lacking (ORAB, 2014; Snyder et al., 2014; Wolancho, 2015). Similarly, Wolka (2014) and Wolancho (2015) report that where structures are constructed on farmers' plots, these are sometimes

[2] Micro-watersheds constitute the intervention units for the CBWM program in a particular *Kebele*.

even destroyed, showing that farmers' willingness to implement watershed management activities is still limited. Hence, it is essential to comprehensively assess conditions that influence farmers' decisions to participate in the CBWM program. Nigussie et al. (2018) explored how the design, implementation, and evaluation of the program is carried out in North-West Ethiopia, using a qualitative research approach. However, this study did not examine the issue of farmers' participation in the program. This paper fills this gap by assessing farmers' level of participation in the CBWM program and the factors that determine this participation in order to suggest conditions that enhance participation and ownership of the program. Following Price and Mylius (1991), participation here refers to engagement or involvement in CBWM activities carried out at the planning, implementation, and post-implementation stages of the program. The study is conducted in three selected *Kebeles* of Boset District, where similar studies have never been conducted.

2.2 Theoretical framework of the study

To understand farmers' decisions to participate in the CBWM program, literature on common-pool resource management is perused (e.g. Wade, 1987; Agrawal, 2001; Ostrom, 2005; Araral, 2009; Ostrom and Cox, 2010; Ostrom, 2011; Ratner et al., 2013). The literature includes rational choice, structuralist, and social constructivist explanations of cooperation. Rational choice models (prisoner's dilemma, the tragedy of the commons, and the logic of collective action) are the earliest attempts to explain collective action in common-pool resources. These models suggest that rational individuals will not cooperate to achieve common goals voluntarily, unless they are coerced by an external body or state (Wade, 1987; Ostrom and Cox, 2010). However, these models ignore the importance of communication and interaction, individuals' knowledge of the situation and payoffs, local actors and rules to enforce agreements among the individuals, and the significance of the resource for the survival of people concerned. Structuralists, on the other hand, acknowledge the possibility of ensuring collective action without external coercion and suggest resource system characteristics, group characteristics, institutional arrangements, and external environment as key enabling conditions of collective action (Agrawal, 2001). This approach, however, formulates prior design principles, ignores people's motivation, and focuses on conditions that influence the emergence of self-governance of resources and group characteristics giving less attention to attributes of group members (Kerr, 2007). Finally, the social constructivists emphasize human awareness and knowledge, motivations, networks, and social experiences in actors' choice of a course of action (Steins and Edwards, 1999). The outcome of actors' actions is considered to be the result of interactions, and hence no prior assumptions (or standards) are made about success or failure (Steins and Edwards, 1999).

This approach, however, leads us to a situation where no reality is privileged over another, as indicated by Hannigan (2006).

Considering the purpose of this study, Ostrom's (2005) Institutional Analysis and Development (IAD) framework was adapted as it draws on the aforementioned explanations and comprehensively describes factors that affect collective action in common-pool resources. This framework acknowledges the importance of external factors in directly influencing internal factors and collective action, as shown in Figure 2.1. In this study, external factors refer to the social and physical environment that encompasses and remains constant for the study *Kebeles*.

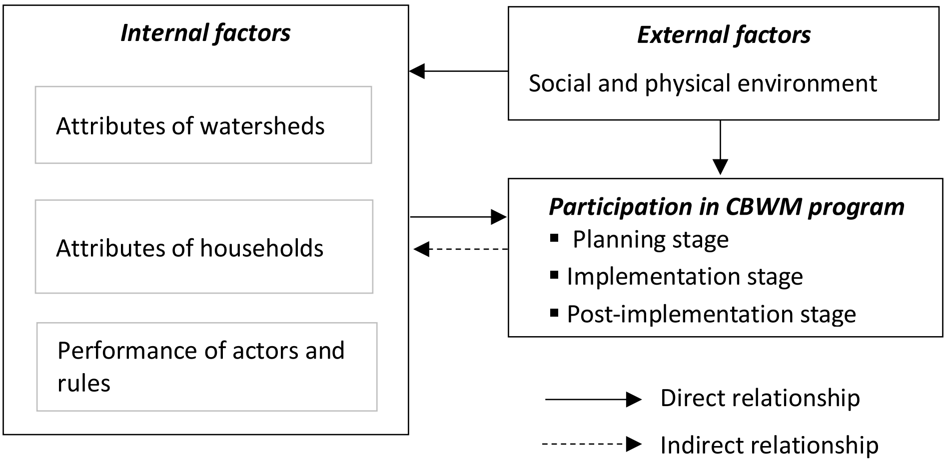

Figure 2.1 Factors that influence farmers' participation in the CBWM program, adapted from Ostrom (2005).

Concerning internal factors, the IAD framework suggests that (1) physical/material conditions, (2) attributes of community, and (3) rules are essential for successful collective action in common-pool resources (Ostrom, 2005). In this study, the "physical/material conditions" is replaced by "attributes of watersheds" since the watershed is a common-pool resource. This internal factor includes farmers' perception of watershed degradation and distance from micro-watersheds. Furthermore, the "attributes of community" is changed to "attributes of households" since the main unit of analysis in this study is a household. This internal factor encompasses various demographic and socio-economic characteristics of households. Finally, "Rules" is broadened to include local actors also, and named "performance of local actors and rules" since local government actors and their rules to mobilize farmers are inseparable. This includes performance of *Kebele* administrators, extension workers, leaders of development teams, and leaders of local networks as well as effectiveness of rules pertaining to campaign works and watershed protection.

Although all the above-mentioned internal factors influence farmers' level of participation in the CBWM program, their influence differs for the planning, implementation, and post-implementation stages of the program. As shown in Figure 2.1, farmers' level of participation in the CBWM program will in turn indirectly influence the internal factors. In the CBWM program, farmers will participate at the *planning stage* by (1) participating in community-wide training, (2) suggesting ideas during community-wide training, (3) making decisions on land/types of tree seedlings to be planted, (4) making decisions on the micro-watersheds to be developed, and (5) making decisions on the scheduling of CBWM activities. At the *implementation stage*, farmers will participate by (1) contributing labor for the construction of SWC structures, (2) contributing/using own working tools to construct SWC structures, (3) motivating fellow farmers to participate in SWC construction, (4) contributing labor to plant tree seedlings, and (5) motivating fellow farmers to participate in planting tree seedlings. Relatedly, farmers participate at the *post-implementation stage* by (1) contributing labor for the maintenance of SWC structures, (2) contributing/using own working tools to maintain SWC structures, (3) motivating fellow farmers to participate in the maintenance of SWC structures, (4) strictly observing rules and regulations pertaining to micro-watersheds protection, and (5) actively protecting the micro-watersheds from destruction by humans and animals.

2.3 Materials and methods

2.3.1 Study Area

This study was carried out in Boset District, Oromia Region. The selection of the District depends largely on the need to narrow down the scope of the study in the face of resource and time constraints, unavailability of similar research studies in the area, and the existence of both success and failures in this District (BDAO 2015), which creates an opportunity to assess specific factors influencing farmers' participation. Boset District has a total land area of 137,849 ha and is located in the Central Rift Valley of Ethiopia, where land degradation, particularly soil fertility depletion and water erosion, seriously affects agricultural production (Adimassu et al., 2012). CSA (2013) estimated the District's total population to be 174,659 in 2013, out of which 78.7% (137,517) lives in rural areas. According to BDFEDO (2012) about 89% of the District belongs to the tropical (*kolla*) agro-climatic zone, while about 11% is subtropical (*woina dega*). The average annual temperature varies between 25-30 °C for the tropical and 15-20 °C for the subtropical zones. The intensity of rainfall varies across different localities in the District, with average annual rainfall ranging between 700 and 800 mm (BDFEDO, 2012). In terms of drainage system, the District falls in the Awash River Basin. According to BDAO (2015), out of the 33 rural *Kebeles* in the District 10 were successful, 14 moderate, and nine weak in terms of their performance of the CBWM program when considering ownership, quality, and quantity of CBWM activities that were carried out between 2011/12 and 2015/16. The program activities are carried out each year in one or more selected micro-watersheds in the *Kebeles*. The main activities are constructing SWC structures, planting tree seedlings, and enclosing the micro-watersheds.

For the purpose of this study, three adjacent *Kebeles* were purposively selected: Ararso-Bero, Sara-Areda, and Qachachule-Guja (Figure 2.2), considering their relative performance in CBWM activities. According to BDAO (2015), Ararso-Bero was the best performing *Kebele* in the District, while performance in Sara-Areda and Qachachule-Guja *Kebeles* was moderately successful and weak, respectively. The study *Kebeles* together include a total of 4,068 households (1449 in Ararso-Bero, 1414 in Sara-Areda, 1205 in Qachachule-Guja) and cover a total area of 10,669 ha; where Ararso-Bero, Sara-Areda, and Qachachule-Guja *Kebeles* constitute 2760 ha, 3913 ha, and 3996 ha respectively (BDAO 2015). As shown in Figure 2.2, five micro-watersheds were developed in Sara-Areda and Qachachule-Guja; while four micro-watersheds were developed in Ararso-Bero. The average area of the micro-watersheds was 13.72 ha, Dhaka-Bora I (2.18 ha) and Qachachule (29.98 ha) being the smallest and largest respectively.

2.3.2 Research design

The research design of this study was a case study consisting of mixed research methods to comprehensively analyze farmers' participation level in CBWM program and factors that determine their participation. First, qualitative research was conducted in August 2016, using key informant interviews and individual case studies. This was followed by a household survey, which was designed based on input obtained from the qualitative research. The survey-based data collection was conducted in January and February 2017.

2.3.3 Methods of data collection

Key informant interviews

Key informant interviews were conducted to identify and analyze decision-making processes of actors (other than farmers) in the CBWM program. Actors were also asked to reflect on driving factors and the process through which farmers make decisions to participate at the planning, implementation and post-implementation stages of the program. Interviews were conducted with 29 purposively selected individuals, including experts in the Oromia Region Natural Resource Conservation and Protection Unit, experts in Boset District Natural

Resource Management Department, a local supervisor, *Kebele* administrators, extension workers, leaders of development teams, and village elders. The individuals were selected based on their involvement in the program as well as their availability during this fieldwork.

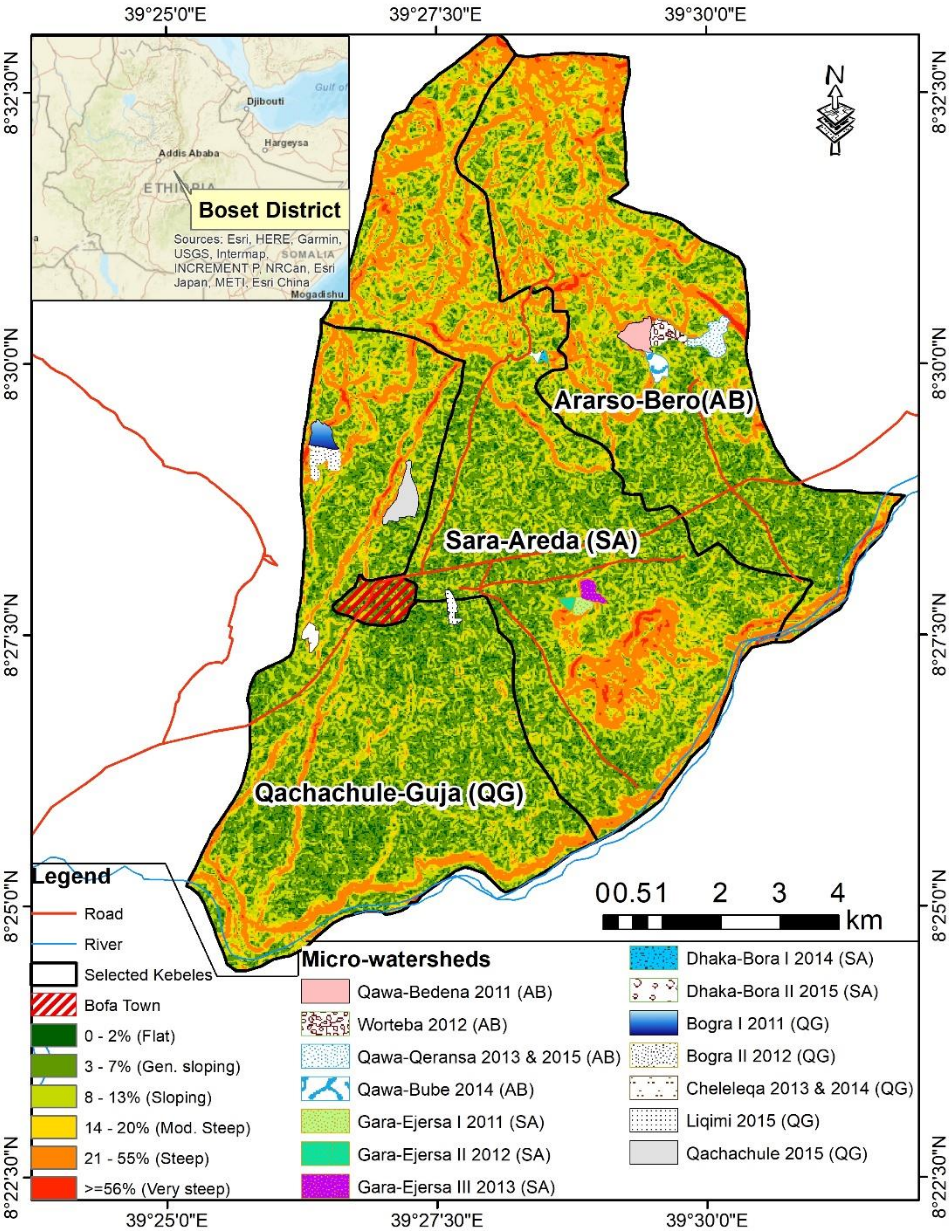

Figure 2.2 Map of the study area: Ethiopia, Boset District, study Kebeles, micro-watersheds and years in which they were developed.

Individual case studies

Individual case studies were conducted with selected farmers to reflect on their personal experiences. Interviews were done in the form of case stories, where informants provided in-depth information on why and how they participated in different stages of the CBWM program. Overall, 15 farmers (five in each *Kebele*) were selected from different wealth status, age, and sex categories.

Household survey

The household survey was used to explain key factors that determine farmers' participation in the CBWM program. The main interest here was to identify the extent to which attributes of watersheds, attributes of households, and performance of local actors and rules affect farmers' level of participation in the program. The survey design selected for this study is cross-sectional. Before selecting samples, a list containing the names of household heads, sex of household heads, the names of local zones, and development teams was prepared and used as a sampling frame. Cochran's (1977) sampling formula was used to select 351 households (125 from Ararso-Bero, 122 from Sara-Areda, and 104 from Qachachule-Guja) using a proportionate stratified systematic sampling technique. A structured draft questionnaire was developed and tested in the field. Both pilot study and actual household survey were conducted by six trained data collectors. Household heads were the respondents of the questionnaire.

2.3.4 Methods of data analysis

Determining farmers' level of participation

Farmers' level of participation was determined based on their level of participation at the planning, implementation, and post-implementation stages of the program. Four scores or dependent variables that represent households' level of participation were calculated: (1) planning stage score, (2) implementation stage score, (3) post-implementation stage score, and (4) the overall CBWM program score. For each stage of the program, five items[3] were used to calculate a score (see Table 2.2 for the items), based on the extent to which households participated at the planning, implementation, and post-implementation stages of the program. The scores for each stage range between 0 and 10. These three scores were summed to determine the overall CBWM program score, which ranges between 0 and 30 and shows households' level of participation in the program as a whole. After determining

3 The items were mainly identified based on key informant interviews and individual case studies that preceded the household survey. For each item, respondents were asked to choose among three categories (0 = Never, 1= to some extent, and 2 = to great extent). They are found to be reliable as measured by Cronbach's alpha (planning stage = 0.868, implementation stage = 0.736, and post implementation stage = 0.708). Values between 0.7 and 0.9 are considered good indicator of reliability of items in a composite measure.

participation scores, descriptive statistics and one-way Analysis of Variance (ANOVA) were used to show the difference in the level of participation across the studied *Kebeles* and stages of the program. Information obtained from key informant interviews and individual case studies was analyzed by organizing data into themes or categories following interview guides, including key actors, their roles and responsibilities, and actual performances during the planning, implementation, and post-implementation stages of the program. This information was used to give context to and substantiate quantitative findings from the household survey.

Determining explanatory variables

Different explanatory variables were selected and tested for their relationship with the aforementioned dependent variables. These explanatory variables are related to the three internal factors (attributes of watersheds, attributes of households, and performance of local actors and rules) specified in the theoretical framework of this study. Overall, 25 explanatory variables were identified and tested for their relationship with the dependent variables. Table 2.1 shows a description of the explanatory variables. Among these variables, only variables that have a statistically significant relationship with the overall CBWM program score were retained for further analysis.

To determine factors that influence households' level of participation, a Negative Binomial Regression Model (Maximum Likelihood Estimation - MLE) was used. According to Cameron and Trivedi (2013), this type of model takes dispersion in the dataset into account and is appropriate for discrete or count data that do not take negative values and decimals. Hence, Negative Binomial Regression Model (MLE) is suitable for the study as the scores of dependent variables are positive integer numbers and represent the level/intensity of participation. In addition, before proceeding to an analysis of parameter estimates, it is recommended to test if the model fits the dataset. A deviance value closer to one is considered an indicator of fit between the model and the dataset. In addition, residual analysis was conducted to assess the normality and homogeneity of variance in the dataset (Dobson, 2002; Hoffman, 2004). Scatterplots were generated for standardized deviance residuals (y-axis) and predicted value of the mean of response (x-axis) to assess the homogeneity of variance. The symmetrical and balanced distribution of the residuals along the x-axis was assessed. Also, the standardized Pearson residual was generated to assess outliers. In both cases, the model is considered to fit the data, when 95% of the residuals are under the absolute value of two.

Table 2.1 *Description of explanatory variables.*

Variables	Units	Percentage/Mean	St. Deviation
Attributes of watersheds			
Households' perception of watershed degradation score	1- 40[a]	33.08	5.20
Households' distance from micro-watersheds	0 = Inside/near, 1 = Somewhat far, 2 = Very far	1.44	0.69
Attributes of households			
Sex of household head (% Male)	0 = Female, 1 = Male	80.9	-
Age of household head	Years	43.5	13.7
Educational level of household head (% Literate)	0 = Illiterate, 1 = Literate	34.4	-
Household size	Labor unit	2.85	1.37
Size of land owned	Qarxi (0.25 hec.)	5.46	3.96
Size of farmland owned	Qarxi	4.64	3.66
Size of cultivated land	Qarxi	5.52	4.39
Livestock ownership (% Yes)	0 = No, 1 = Yes	78.3	-
Livestock size	Tropical livestock unit	2.22	2.18
Participation in off-farm activities (% Yes)	0 = No, 1 = Yes	25.1	-
Income obtained from off-farm activities	Birr[b]	1795	1966
Participation in non-farm activities (% Yes)	0 = No, 1 = Yes	17	-
Income obtained from non-farm activities	Birr	4977	7231
Amount of credit received	Birr	2480	2352
Amount of savings	Birr	1625	3306
Degree of participation in the decision-making of local organizations score	1-30[c]	8.34	3.33
Households' social capital score	5-20[d]	14.90	2.02
Performance of local actors and rules			
Performance of leaders of development teams score	1-10[e]	7.59	1.52
Performance of extension workers score	1-10[e]	6.84	1.75
Performance of *Kebele* administrators score	1-10[e]	6.59	2.65
Effectiveness of leaders of local network (% Effective)	0 = Not effective, 1 = Effective[e]	87.3	-
Effectiveness of rules for campaign works (% Effective)	0 = Not effective, 1 = Effective[e]	76	-
Effectiveness of rules for maintenance/ protection of conservation measures in developed micro-watersheds (% Effective)	0 = Not effective, 1 = Effective[e]	68.1	-

[a] Based on five items that assess how farmers rate the problem of soil fertility depletion, water erosion, diminishing size of grassland, deforestation, and shortage of rain.

[b] 1 birr = 0.04532 USD, in 27 May 2016.

[c] Based on ten items that assess farmers' extent of participation in the decision-making of local networks, development teams, local surveying committee, micro-watershed associations, Village Saving and Loan Associations, indigenous organization (*iddir*, *iqub*), school and health committees, and agricultural cooperatives.

[d] Based on five items that assess farmers' active participation in organizations/associations, voluntarily work collectively with other fellow farmers, reciprocity, trust, and networks.

[e] Based on farmers' own ratings of the performance/effectiveness of the specified local actors and rules.

The Omnibus Test or Likelihood Ratio Chi-square and the Incidence Rate Ratio or E (B) are two key tests that help to understand the result of the Negative Binomial Regression Model (MLE) (Cameron and Trivedi, 2013). The Omnibus Test or Likelihood Ratio Chi-square shows the statistical significance of the combined contribution of the explanatory variables over the intercept-only model. The Incidence Rate Ratio or E (B) indicates the percentage change of a dependent variable due to an explanatory variable. An E (B) value of one is an indication of no relationship between a dependent and explanatory variable, whereas a value above one and below one indicates a positive and negative relationship respectively. The more the value of E (B) deviates from one, the higher its contribution to a dependent variable. Accordingly, E (B) was used to identify factors and rank them based on their relative contribution to the overall CBWM program score. Information obtained from key informants and individual case studies was organized following key factors influencing farmers' participation at different stages of the program. Finally, results obtained from the Negative Binomial Regression Model (MLE) were substantiated by information obtained from key informant interviews and individual case studies.

2.4 Results and discussions

2.4.1 Farmers' level of participation in the CBWM Program

On the scale that ranges between 0 and 30 (0 = lowest, 30 = highest), the mean overall households' level of participation in the CBWM program was 15.91 (53.0%). The level of participation was highest in Sara-Areda, while this was moderate and weak in Qachachule-Guja and Ararso-Bero respectively (Table 2.2). One-way ANOVA confirms that the mean difference between the *Kebeles* was statistically significant at $P<0.01$ ($F=63.01$). The following paragraphs discuss farmers' level of participation and mechanisms of participation at the planning, implementation, and post-implementation stages of the program.

Planning stage: The participation of farmers at the planning stage of the program is critical since this is likely to enable government actors to incorporate the needs, views, and aspirations of farmers. However, according to key informants (extension workers, experts in the District and the Region), plans are prepared following administrative boundaries or *Kebeles*. The key informants also stated that the planning process has been top-down, where the Regional, Zonal, District, and *Kebele* level government actors make almost all critical decisions, including the need for watershed management, micro-watersheds to be developed, type and quantity of activities, and allocation of material and human resources. This shows that despite claims that natural resource conservation in Ethiopia follows a bottom-up approach (Desta et al., 2005), in practice the planning of the CBWM program is still top-down with limited participation of farmers in decision-making (Snyder et al*.*, 2014; Nigussie et al*.*, 2018). The extension workers stated that the plans have been over-ambitious and some activities do not fit local contexts. This has created a state of confusion and lack of ownership of the plan by local actors, including farmers. Though extension workers are required to do some planning, they are obliged to implement the type and quantity of SWC structures and seedlings handed over from higher-level government actors. Consistently, Abi (2019) stated that plans that are prepared by extension workers at the *Kebele* level are hardly implemented, since they are obliged to embrace those prepared at the Regional level. *Kebeles* rarely try to accomplish the activities as per the plan. They instead submit false reports to the District administration to please higher authorities, as also shown by Nigussie et al*.* (2018). According to extension workers and *Kebele* administrators, farmers are informed about watershed management in a meeting, where government actors introduce their plan and make a verbal agreement with farmers on a specific implementation plan. The acceptance of the plans by the farmers is verified as positive when farmers don't openly oppose the plans and endorse them by clapping their hands.

Table 2.2 *Mean households' level of participation at each stage of the CBWM program.*

	Stages	Ararso-Bero	Sara-Areda	Qachachule-Guja	All Kebeles
A	Planning stage				
1	Participating in community-wide training	1.06	1.41	1.02	1.16
2	Suggesting ideas during community-wide training	0.32	0.84	1.23	0.80
3	Making decision on land/types of seedlings to be planted in the developed micro-watersheds	0.15	0.71	1.30	0.72
4	Making decision on the micro-watersheds to be developed	0.14	0.63	1.28	0.68
5	Making decision on schedule of CBWM activities	0.25	1.21	1.15	0.87
	Planning stage score (0 = lowest, 10= highest)	1.92 (19.2%)	4.80 (48%)	5.98 (59.8%)	4.23 (42.3%)
B	Implementation stage				
1	Contributing labor for the construction of SWC structures	1.57	1.94	1.37	1.63
2	Contributing/using own working tools to construct SWC structures	1.19	1.81	1.22	1.41
3	Motivating fellow farmers to participate in SWC construction	0.83	1.08	1.06	0.99
4	Contributing labor to plant seedlings	1.04	1.78	1.36	1.39
5	Motivating fellow farmers to participate in planting seedlings	0.66	1.04	1.07	0.92
	Implementation stage score (0 = lowest, 10 = highest)	5.29 (52.9%)	7.65 (76.5%)	6.08 (60.8%)	6.34 (63.4%)
C	Post-implementation stage				
1	Contributing labor for the maintenance of SWC structures	1.54	1.83	1.02	1.46
2	Contributing/using own working tools to maintain SWC structures	1.25	1.74	1.14	1.38
3	Motivating fellow farmers to participate in the maintenance of SWC structures	0.80	0.99	0.36	0.72

	Stages	Ararso-Bero	Sara-Areda	Qachachule-Guja	All Kebeles
4	Strictly observing rules and regulations pertaining to micro-watersheds protection	1.11	1.58	0.23	0.97
5	Protecting the micro-watersheds from destruction by humans and animals	0.77	1.13	0.52	0.81
	Post-implementation stage score (0 = lowest, 10 = highest)	5.47 (54.7%)	7.27 (72.7%)	3.27 (32.7%)	5.34 (53.4%)
Overall CBWM program score (0 = lowest, 30 = highest)		12.68 (42.3%)	19.72 (65.7%)	15.33 (51.1%)	15.91 (53.0%)

Implementation stage: Farmers are mobilized to participate at the implementation stage of the CBWM program by different actors. During campaign works, experts and cabinet members of the District are required to stay in the *Kebeles* to give technical assistance and strictly enforce community mobilization respectively. But key informants (experts in the District, extension workers, *Kebele* administrators) stated that technical assistance is rarely provided in the field due to a shortage of logistics and mismanagement of the budget allocated for this purpose. The key informants also explained that *Kebele* administrators lack commitment since they are not salaried employees and already have a high work burden. Furthermore, they stated that extension workers have low performance because of limited skills, knowledge and commitment, and many non-agricultural assignments given to them by higher authorities. Leaders of development teams and local networks are the first contacts for local government actors to mobilize farmers for campaign works, though the key informants vowed that the absence of any written provision regulating the participation of farmers in campaign works is a challenge. However, according to *Kebele* administrators, three strategies have been effectively employed to enhance participation in campaign works: labeling farmers who fail to participate; reprimanding or scolding farmers; and excluding non-participating farmers from different services such as food aid, improved seeds, fertilizers, and other aids sponsored by Non-Governmental Organizations. As shown by Abi (2019), these strategies are essentially coercive and less likely to ensure intrinsic motivation and genuine participation in the program. However, both key informants and farmers (from individual case studies) stated that the timing of the campaign work is generally convenient as the activities are carried out either after harvesting (constructing SWC structures) or cultivation (planting tree seedlings) periods. Although in principle all adults are required to participate in campaign works, in practice only one member from each household is assigned to participate. Even so, the shortage of working tools has been a major limitation during campaign works, given that farmers are supposed to utilize their own tools.

Post-implementation stage: Farmers participate at the post-implementation stage of the program by maintaining SWC structures and protecting the micro-watersheds. In principle, once the construction of SWC structures is completed in micro-watersheds, *Kebele* administrators are expected to hand over the micro-watersheds on communal land and private farmland to associations who are responsible for the maintenance and protection activities, and individual owners respectively. But, according to key informants (extension workers, leaders of development teams), *Kebele* administrators and higher authorities in the District hardly give follow-up to the maintenance and protection of the micro-watersheds. They also stated that the associations rarely undertake maintenance actions due to their poor institutional, financial and technical capacities. As a result, for instance, in Ararso-Bero, all farmers are required to carry out some kind of maintenance before proceeding to regular annual SWC construction. In Sara-Areda, the responsibility to maintain the structures and protect the micro-watershed rests only on the associations. In Qachachule-Guja, not a single micro-watershed was handed over to associations and all *Kebele* level government actors and farmers (from individual case studies) affirmed that there has not been any maintenance and protection of the micro-watersheds. In this *Kebele,* in addition, rules and regulations pertaining to the protection of the micro-watersheds have not been developed and used. This was different in the other two *Kebeles*. The above results are consistent with the findings of Snyder et al. (2014) and Wolancho (2015), who indicated that ensuring maintenance of the SWC structures constructed though campaign works is the main challenge.

Overall, households' level of participation was highest at the implementation stage (63.4%) and lowest at the planning stage (42.3%) of the CBWM program. The participation of households at the post-implementation stage (53.4%) was moderate (Table 2.2). One-way ANOVA confirms that the mean difference between the stages was statistically significant at $P<0.01$ ($F = 63.01$). The difference in the level of participation among the stages could be generally related to variances in the strictness of local actors to mobilize farmers. As shown in the preceding paragraphs, at the planning stage, local government actors rarely require or even invite farmers to participate. Even so, plans prepared at the *Kebele* levels are hardly implemented because of the obligation to implement those that are handed over from higher-level government actors. At the implementation stage, all farmers are required to contribute labor, whereas at the post-implementation stage, the responsibility to contribute labor rested mainly on members of the micro-watershed associations (communal land) and individual owners (private farmland). At all stages, the top-down approach by higher government authorities was the main obstacle to consider needs, views, and aspirations of the farmers.

2.4.2 Factors influencing farmers' level of participation in the CBWM program

The result of the Likelihood Ratio Chi-square test shows that out of the 25 factors, seven factors together significantly improved the model over the intercept-only model (Table 2.3). These factors are ranked based on their value of Incidence Rate Ratio or E (B) and discussed below.

Participation in off-farm activities: The first factor that significantly influenced households' level of participation in the CBWM program was participation in off-farm activities. The participation level of households who did not engage in off-farm activities was 24.2% higher than households who engaged in off-farm activities. According to key informants (extension workers, village elders), farmers engage in off-farm activities when their own agricultural activities fail to provide sufficient livelihood sources. Such farmers usually migrate to other localities (rural and town) in search of temporary employment, which limits their participation in the program. This finding is consistent with other empirical results (e.g. Agrawal and Yadama, 1997; Dillon, 2011; Wang et al., 2016) showing a negative effect of seasonal out-migration on collective action for common-pool resource management in rural communities. The effect of off-farm activities was quite significant in Ararso-Bero, and at all stages of the CBWM program (Table 2.3). This higher effect of off-farm activities in Ararso-Bero could be related to lower household agricultural outputs since farmers cultivate small areas of farmland (3.17 *Qarxi*), compared to Sara-Areda (4.91 *Qarxi*) and Qachachule-Guja (6.88 *Qarxi*).

Effectiveness of leaders of local networks: The second factor that significantly influenced households' level of participation was the effectiveness of the leaders of local networks as perceived by the households. The level of participation for households from networks with more effective leaders was 19.7% higher than for households with less effective leaders. Other empirical evidences (e.g. Kacho and Asfaw, 2014) also show that the commitment of leaders of the community is essential for successful watershed management. The influence of leaders of local networks was particularly important in Qachachule-Guja. This could be because leaders of local networks from rural areas are more effective than those who live both in towns (e.g. Bofa town) and rural areas. The performance of the latter is usually lower since they are busy with their non-farm activities in town. In addition, the influence of leaders of local networks was the highest at the post-implementation stage of the program. This indicates that the commitment/performance of leaders of local networks is crucial for the maintenance and conservation of micro-watersheds. At the planning stage, the participation level was higher for households from networks with less effective leaders (Table 2.3). This may be explained by the fact that leaders of local networks hardly force farmers to participate at this stage. In addition, some farmers might have participated in the planning activities (e.g. community-wide meetings) to express their grievances about the performance of leaders of their networks.

Table 2.3 *Summary of Incidence Rate Ratio or E (B) for households' level of participation in the CBWM program.*

Factors	Stages			Overall level of participation			
	Planning	Imple-menta-tion	Post-imple-mentation	Ararso-Bero	Sara-Areda	Qachachule-Guja	All Kebeles
Participation in off-farm activities	0.587***	0.760***	0.898*	0.829***	0.997	0.902	0.758***
Effectiveness of leaders of local networks	0.757**	1.151	2.005***	1.057	1.000	1.235***	1.197**
Educational level of household head	1.195**	1.088*	1.014	1.167**	0.992	1.130*	1.097**
Households' distance from micro-watersheds	1.147**	0.940*	0.866***	0.811***	0.961	0.976	0.951*
Households' social capital	1.077**	1.053***	1.016	1.043	1.048***	1.018	1.046***
Households' degree of participation in the decision-making of local organizations	1.052***	1.024***	1.029***	1.052***	1.033***	1.025*	1.031***
Households' perception of watershed degradation	0.998	1.007	1.028***	1.040***	1.009	0.981**	1.011**
Goodness of fit/ Deviance (value/df)	1.194	0.656	0.998	1.495	0.955	0.897	1.162
Omnibus Test /Likelihood Ratio χ^2	68.33***	91.606***	161.140***	58.873***	39.418***	43.403***	137.567***
Scatterplot for deviance residual vs. predicted mean (% between -2 & 2)	100^{e}	100^{e}	100^{e}	100^{e}	100^{e}	100^{e}	100^{e}
Pearson residual (% between -2 & 2)	97.2	99.7	96.9	91.8	95.8	96.0	94.3
N	286	290	292	110	95	75	280

**P<0.1 **P<0.05 *** P <0.01* ^{e} Residuals are symmetrically distributed and balanced along x-axis; no significant deviation away from 0.

Educational level of household head: Education was the third most important factor that positively predicted households' level of participation in the program. The level of participation for literate households was 9.7% higher than illiterate households. Other studies (e.g. Huilan, et al., 2009; Willy et al., 2016) also show that education significantly contributes to successful collective action in common-pool resources. The influence of education was particularly significant in Ararso-Bero and Qachachule-Guja (Table 2.3). This could be attributed to the higher literacy rate among some farmers in Ararso-Bero (due to their out-migration or exposure to the outside world) and Qachachule-Guja (due to their better access to schools in Bofa town). In addition, the effect of education was more important at the planning and implementation stages of the program, maybe because some of the more educated famers are also leaders of different local organizations, who are usually expected to be exemplary for other fellow farmers during community-wide training and campaign works.

Households' distance from micro-watersheds: The fourth factor that significantly influenced households' level of participation was the distance of the micro-watersheds from the homesteads of households. A unit increase of this factor reduced households' level of participation by 4.9%. Overall, the participation level of farmers that are far away from the micro-watersheds was limited. Previous empirical results (e.g. Okumu and Muchapondwa, 2017) also show that farmers who are far away from common-pool resources are less likely to engage in the collective management of the resources. The effect of distance was quite substantial in Ararso-Bero, perhaps due to the fact that all micro-watersheds are located on communal land relatively far away from the settlement area. In addition, this factor significantly influenced farmers' level of participation at the implementation and post-implementation stages of the program, since farmers from all corners of the *Kebeles* are required to work on one or two micro-watersheds during campaign works. This is confirmed by key informants (village elders, leaders of development teams) and farmers (from individual case studies) who state that some farmers walk for about two hours per day to work on the micro-watersheds during campaign works. Such farmers will not have a sense of ownership of the micro-watersheds. However, at the planning stage, the participation level was higher for farmers that were far away from the micro-watersheds (Table 2.3). This occurred because some planning activities were carried out in the *Kebele* administration offices, not in the micro-watersheds. It appears that these offices were more accessible for farmers that were far away from the micro-watersheds.

Households' social capital: Social capital was the fifth factor that influenced households' level of participation, with a unit increase in its score increased households' level of participation by 4.6%. This finding is in agreement with other empirical studies (e.g. Ohno et al., 2010; Willy et al., 2016) that emphasize the significance of social capital for collective watershed management. The influence of social capital was particularly significant in Sara-Areda (Table 2.3). This indicates that some farmers have stronger mutual trust and networks, which facilitate flows of information and collective action during campaign works. In addition, this factor was significant at the planning and implementation stages of the program, which indicates the importance of collective actions, mutual trust, and networks at these stages.

Households' degree of participation in the decision-making of local organizations: Participation in the decision-making was the sixth factor that influenced households' level of participation, with a unit increase in its score increasing the households' level of participation by 3.1%. This indicates that the level of participation was higher for farmers that were taking part in the leadership of different local organizations such as development teams, indigenous organizations, committees, and associations. This factor was important in all the studied *Kebeles* and stages of the program (Table 2.3). The absence of differences may be related to the similarity between the *Kebeles* in terms of not only the types, structures, and roles of the local organizations; but also the actual participation of their leadership in different activities of the program.

Households' perception of watershed degradation: The seventh factor that predicted the households' level of participation was the seriousness of watershed degradation as perceived by the households. Households' level of participation increased by 1.1% for a unit increase in households' perception of watershed degradation score. The influence of this factor was particularly significant in Ararso-Bero. This may be because in this *Kebele* runoff water sometimes damages agricultural fields adjacent to communal lands. In Qachachule-Guja, participation level was lower for farmers with a higher perception of watershed degradation. A possible explanation is that farmers who are more aware of watershed degradation are also the ones who are more active with non-farm activities. In addition, this factor was significant at the post-implementation stage of the program. This means the awareness of watershed degradation is more crucial for the maintenance and conservation of the micro-watersheds. Overall, there was a positive (but weak) relationship between farmers' perception of watershed degradation and their level of participation in the program. However, studies in common-pool resources (e.g. Uphoff, et al., 1990; Araral, 2009) indicate that the perception of resource scarcity has a curvilinear effect on the level of collective action for its management. This means that collective action is more difficult when the resource is either very scarce or abundant. Hence, there is a need to further study the effect of watershed degradation on farmers' level of participation in the CBWM program.

In summary, seven factors influenced farmers' level of participation in the CBWM program, but with different effects across the studied *Kebeles* and stages of the program. These factors can be categorized into three key factors: *location or proximity of farmers to the micro-watersheds* (distance from micro-watersheds, participation in off-farm activities in other localities), *commitment of local leaders* to mobilize farmers (effectiveness of leaders of local networks), and *awareness and motivation of farmers* to participate in the program (education, perception of watershed degradation, social capital, degree of participation in the decision-making of local organizations). The awareness and motivation of farmers influenced their level of participation in all *Kebeles*, while location or proximity of farmers and the commitments of local leaders were critical factors in Ararso-Bero and Qachachule-Guja respectively. Similarly, the awareness and motivation, and location or proximity of farmers were important factors at all stages of the program; while the commitment of local leaders was essential at the post-implementation stage.

2.5 Conclusions

The study reveals that farmers' level of participation in the CBWM program was quite low (53.0%). Compared to the implementation and post-implementation stages, the level of participation was lowest at the planning stage of the program. This is because local government actors rarely require or even invite farmers to participate at this stage. *Location or proximity of farmers to the micro-watersheds, commitment of local leaders,* and the *awareness and motivation of farmers* were key factors that influenced farmers' level of participation in the program. This result suggests the need to implement the following recommendations. Although directly applicable to the study *Kebeles*, they could be used to facilitate the participation of farmers in collective watershed management in other parts of the world.

(1) *Focus on smaller watersheds*. Distance from micro-watersheds limits the availability of farmers. Focusing on smaller watersheds minimizes the effect of distance since farmers will work in their neighborhoods, and enhances a sense of ownership of the watersheds.

(2) *Enhance farmers' awareness and motivation.* Participation level was higher for more dynamic or intrinsically motivated farmers. Local government actors should therefore motivate farmers through awareness raising training, literacy education, and capacity building of local organizations so that these organizations engage in collective actions, facilitate mutual trust and networks, and empower farmers to participate in the decision-making processes.

(3) *Include local livelihood opportunities to apply a more integrated approach*. Out-migration for off-farm employment limits the availability of farmers to participate

in the program. This suggests the need to ensure the integration and diversity of the program activities for better local livelihood opportunities. Such integration will enhance the achievement of both natural resource development and livelihood improvement goals.

(4) *Enhance the performance/commitment of local leaders*. The effectiveness of leaders of local networks was critical for farmers' participation in the program. Hence, it is essential to empower and motivate local leaders through capacity building training to develop their sense of ownership of the program so that they can motivate other farmers to engage in the program.

However, given that the effect of the aforementioned factors varies across the studied *Kebeles* and stages of the program, the current blueprint top-down approach of the program in the study area should be replaced by a bottom-up approach. This indicates the need to consider specific socio-economic and biophysical contexts of the *Kebeles* during the planning stage of the program. One possible way is to design and implement the program at the *Kebele* level by giving capacity building training and empowering local actors. Such an approach will enhance participatory planning since farmers are likely to be better able to express their needs, views, and aspirations. This requires changes in the mindset of higher-level government actors so that they give room for local actors to plan and implement the program in their localities, as such to enhancing a higher level of participation, better outcomes, and ownership of the program.

3. Assessing farmers' willingness to participate in campaign-based watershed management: Experiences from Boset District, Ethiopia

This study assessed farmers' perceptions of the outcomes of the Campaign-Based Watershed Management (CBWM) program in Ethiopia, and how this influences their willingness to participate in the program. Key informant interviews, a household survey, and the Google Earth Engine were used to collect and analyze the relevant data. Results show that farmers' perceived outcomes of the CBWM program hardly motivated them to participate in the program. Particularly, farmers were not motivated by the physical effects of the program, because of the limited direct benefits to individual households, and destruction of previously developed micro-watersheds by frequent runoff and human and animal disturbances. Similarly, farmers were not motivated by the economic effects of the program, because of the limitations/absence of benefit-sharing mechanisms and resultant conflicts among farmers. The only motivating outcome of the program concerned its effect on personal capacities, which was particularly appreciated in localities that were vulnerable to erosion. The results of the study suggest the need to (1) better integrate actions at watershed level to come to effective water runoff control, (2) enhance the participation of all local actors to come to more effective area closure initiatives with transparent benefit-sharing mechanisms, and (3) give much more emphasis to capacity building as a cross-cutting component in the program. Hence, in order to enhance the willingness of farmers to genuinely participate in the CBWM, the program should adopt a more participatory and integrated approach.

Based on:

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3.1 Introduction

Watershed management approaches became prominent in developing countries in the 1970s and 1980s in programs designed to manage soil and water resources through conservation measures (Darghouth et al., 2008; Erdogan, 2013). The achievements of these programs have been measured in terms of quantity of Soil and Water Conservation (SWC) structures. In Ethiopia, some success stories were documented, particularly with regards to the lengths of SWC structures and area of land enclosed for regeneration during the Derg regime - a communist government that ruled Ethiopia between 1974 and 1991 (Desta et al., 2005; Tongul and Hobson, 2013). For instance, between 1976 and 1985, some 600,000 km of soil and stone bunds and 470,000 km of hillside terraces were constructed through campaign works. During the same period, 80,000 ha of steep slopes were enclosed for regeneration (Wood and Stahl, 1990; Zeleke, 2006). However, this initiative was not sustainable, mainly because little attention was given to rural livelihoods, and views and perceptions of farmers (Wood and Stahl, 1990).

The current government has continued with campaign works as part of the national Campaign-Based Watershed Management (CBWM) program since 2011/12. The program is carried out according to *Kebele*/village administrative boundaries by means of mass mobilization of farmers. Given a shift in watershed management to a more comprehensive approach integrating both resource conservation and rural livelihood development in developing countries since 1990s (Darghouth et al., 2008), the program adopted community-based participatory watershed development as its main guiding principle (Desta et al., 2005). The CBWM program seeks to cover a large area in a short period of time, to minimize costs, and to ensure farmers' ownership of the program. It has three main elements: (1) identify one or more micro-watersheds every year, (2) construct SWC structures and plant tree seedlings in the micro-watersheds, and (3) hand over the micro-watersheds on communal land and private farmland to micro-watershed associations and individual owners respectively. The government has been reporting success stories in terms of the area of land covered, lengths of SWC structures, and numbers of tree seedlings planted. However, a study that comprehensively assesses outcomes of the CBWM program is not available, as the existing empirical evidence on Ethiopia generally focuses on outcomes of project-based interventions that are carried out through food-for-work payments or incentives (Tongul and Hobson, 2013; AgWater Solutions, 2012; Mazengia and Mowo, 2013; Adimassu et al., 2013). Equally important as qualitative outcomes are the actors' perception of these outcomes, given that this often determines subsequent successful collective action (Meinzen-Dick et al., 1997; Agrawal, 2001; Fujiie et al., 2005; Miyashita, 2009) and sustainable land management (Snyder et al., 2014; Kessler et al., 2016). Hence, next to quantifying outcomes, it is indispensable to also assess farmers' perceptions of outcomes of watershed management initiatives. Though mass mobilization remains an essential strategy to engage farmers, the relationship between farmers' perceptions of previous outcomes of the CBWM program and their willingness to participate in the program has never been assessed so far. This paper aims at filling this gap, and explores how farmers' perceptions of physical works as well as changes in biophysical and socio-economic conditions influence their willingness to participate in the program.

3.2 Conceptual framework of the study

The CBWM program is a collective watershed management initiative since it relies on the mass mobilization of farmers for labor contribution. Considering this, selected literature on the effects of collective action in environmental rehabilitation activities (e.g. Swallow et al., 2006; Shiferaw, 2008) was examined to guide an assessment of the linkage between farmers' perceived outcomes of the CBWM program and its implication for their willingness to participate in the program. However, a more specific conceptual framework that explains this relationship was not found. Much SWC-related research in Ethiopia is fragmented, focusing on biophysical (Nyssen et al., 2010; Taye et al., 2013; Taye et al., 2015) and economic returns (Nyssen et al., 2007; Kassie et al., 2011; Adgo et al., 2013) of project-based SWC structures. Hence, a more contextual conceptual framework is developed based on the collective action literature, SWC-related empirical evidence in Ethiopia, objectives of the CBWM program, and farmers' expected outcomes of the program. The framework succinctly explains how different outcomes of a CBWM program are related to each other, and how this influences farmers' willingness to participate in the program, as shown in Figure 3.1.

The framework shows that a CBWM program results in three outcomes: executed physical works, change in biophysical conditions, and change in socio-economic conditions. The program initially results in the physical works, which encompasses the lengths and quality of SWC structures as well as number and quality of tree seedlings planted in the micro-watersheds. Biophysical conditions involve the outcomes of the CBWM program in terms of controlling runoff, moisture retention, soil fertility improvement, and vegetation cover. The contribution of the program to biophysical conditions is dependent on the physical works. Socio-economic conditions could be short-term outcomes of the CBWM program such as farmers' access to communal grazing land, access to grass, knowledge and skills, income from the sale of grass, and replication of the program to other localities. In the long-term, improved biophysical conditions could contribute to the improvements of agricultural production and productivity, which enhances socio-economic conditions of farmers. The framework indicates that farmers' perceptions of the aforementioned outcomes will influence their willingness to participate in the program.

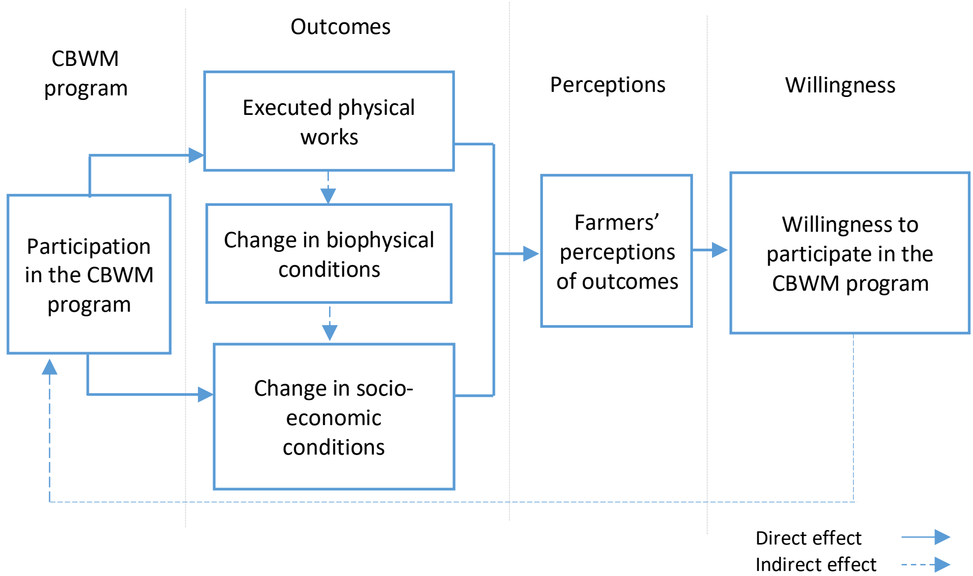

Figure 3.1 Linkage between outcomes of the CBWM program and farmers' willingness to participate in the program.

3.3 Materials and methods

3.3.1 Study area

This study was carried out in Boset District in the Central Rift Valley of Ethiopia. The District has experienced an increase in soil erosion rates over the past decades, with annual rates of 31 t ha^{-1} in 1973 and 56 t ha^{-1} in 2006 (Meshesha et al., 2012; Meshesha et al., 2014). Among the 33 rural *Kebeles* in the District, Ararso-Bero, Sara-Areda, and Qachachule-Guja were selected based on their performance in the CBWM program. According to BDAO (2015), Ararso-Bero is the best performing *Kebele* in the District, while Sara-Areda and Qachachule-Guja are moderate and weak, respectively, when considering ownership, quality, and quantity of watershed management activities as criteria. These *Kebeles* are adjacent to each other and there has not been another environmental rehabilitation initiative in the *Kebeles*, other than the CBWM program.

3.3.2 Methods of data collection

In order to collect the data, a mixed research method was employed. Key informant interviews and a household survey were conducted between August 2016 and February

2017. Google Earth Engine was also used to estimate some outcomes (area of micro-watersheds, lengths of SWC structures, vegetation cover). Subsequent paragraphs describe specific methods employed for data collection.

Key informant interviews were conducted to assess local actors' view of the outcomes of the CBWM program, focusing on quality of physical works, biophysical conditions, and socio-economic conditions. Interviews were conducted with 27 purposively selected informants partaking in the CBWM program including experts at Boset District Natural Resource Management and Protection Unit, a local supervisor, *Kebele* administrators, extension workers, leaders of development teams, and village elders. They were selected based on their degree of influence and involvement in the program as well as their availability during fieldwork.

The household survey largely drew on input data obtained from key informant interviews. It was used to assess the perspectives of farmers, focusing on farmers' rating of the quality of physical works as well as changes in biophysical and socio-economic conditions. It was also used to assess farmers' willingness to participate in the program. A structured draft questionnaire was developed and pilot tested in the field. Necessary adjustments were made to the final version of the questionnaire based on the lessons obtained from the pilot study. Both the pilot study and actual survey were conducted by six trained data collectors, and household heads were the main respondents of the questionnaire. A proportionate stratified systematic sampling technique was used to select 351 households (125 from Ararso-Bero, 122 from Sara-Areda, and 104 from Qachachule-Guja) from 4068 households living in the three *Kebeles* (1449 in Ararso-Bero, 1414 in Sara-Areda, and 1205 in Qachachule-Guja).

Google Earth Engine was used to estimate the area of micro-watersheds, lengths of stone bunds and soil bunds, and change in vegetation cover using images taken in 2009 and 2016.

3.3.3 Methods of data analysis

Outcomes of the CBWM program

The analysis of outcomes of the CBWM program was based on data obtained from key informant interviews and Google Earth Engine to substantiate the views of the informants. Data obtained from the key informant interviews were organized into themes following interview guides and a separate transcription report of the results was prepared. Descriptive statistics were used to present areas of micro-watersheds, lengths of SWC structures, and vegetation cover.

Farmers' perceptions of outcomes of the CBWM program

Factor analysis was used to extract some concrete uncorrelated factors or latent variables from 15 items that assessed farmers' perceived outcomes of the CBWM program, as shown in Table 3.1. The items were mainly obtained from the key informant interviews that preceded the household survey (see Section 3.4.1). Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test were carried out to explore if using factor analysis was appropriate for the data at hand (Tucker and MacCallum, 1997). The KMO was highly promising with 0.849 (>0.5 is acceptable), and Bartlett's test of sphericity also showed that the correlation matrix is appropriate for factor analysis ($\chi^2 = 2406.65$, $p > 0.01$) (Tucker and MacCallum, 1997).

Table 3.1 *Description of indicators of farmers' perception of outcomes.*

No	Households' Perceived Outcomes	Values 0	1	2	Mean	Range
1	Quality/proper construction of SWC structures	Not properly constructed	Partly properly constructed	All properly constructed	0.98	2
2	Compatibility/appropriateness of planted tree seedlings	Not appropriate at all	Some are appropriate	All are appropriate	0.86	2
3	Survival of planted seedlings	All haven't survived	Very few survived	Most survived	0.93	2
4	Effect on runoff control	No effect at all	Moderate effect	Significant effect	1.30	2
5	Effect on moisture retention	No effect at all	Moderate effect	Significant effect	1.25	2
6	Effect on soil fertility improvement	No effect at all	Moderate effect	Significant effect	1.34	2
7	Effect on vegetation cover	No effect at all	Moderate effect	Significant effect	1.25	2
8	Obtained knowledge	No, not at all	Yes, somewhat	Yes, all required knowledge	0.69	1
9	Obtained skill	No, not at all	Yes, somewhat	Yes, all required skills	0.76	2
10	Constructing SWC structures on their land on their own	No, not at all	Yes, in few places	Yes, in all places	0.44	2
11	Access to communal land	Decreased	No change	Increased	0.75	2
12	Access to grass	Decreased	No change	Increased	0.93	2
13	Income (birr)	≤ 850	851-1700	>1700	0.05	2
14	Size of farmland	Decreased	No change	Increased	1.33	1
15	Size of grazing land	Decreased	No change	Increased	1.00	2

A varimax orthogonal rotation method was used to select and include indicators that have higher factor loading (i.e., greater than 0.4) to the newly identified factors or latent variables (Field, 2009). Each factor was attributed a name according to the set of indicators it encompasses. Eigenvalue (>1) was used to determine the number of factors to extract. A scree plot was used to examine the graph of the eigenvalues and visually see the number of factors to retain. Descriptive statistics and one-way ANOVA were used to determine farmers' perceptions of outcomes of the program and test for statistically significant differences between the *Kebeles*, respectively.

Farmers' willingness to participate in the CBWM program

Farmers' willingness to participate in the CBWM program was determined by asking each farm household to rate (0 = Strongly disagree, 1 = Disagree, 2 = Agree, 3 = Strongly agree) to what extent they agree with the following seven items. The items were mainly obtained from the key informant interviews that preceded the household survey and were refined based on pilot household survey results.

- I found trainings given before starting campaign works useful and valuable.
- I have a firm belief that the CBWM program contributes to ecosystem restoration or livelihood improvement.
- I am in favor of the construction of SWC structures on my farmland and communal land that I am using.
- I have been enthusiastically contributing labor for campaign works.
- Since I have been in favor of the CBWM program, I have been using my own working tools during campaign works.
- I have been participating in the CBWM program by my own initiative; not because of external pressure or persuasion.
- I have been eagerly contributing to the maintenance and protection of micro-watersheds.

Cronbach alpha was used to assess reliability or internal consistency of the items. The Cronbach alpha value for these items was 0.7; values from 0.7 to 0.9 are considered a good indicator of the reliability of items in a composite measure (Bland and Altman, 1997). Next, a willingness score was calculated for each household by summing responses to each item. One-way ANOVA was used to show the difference in willingness level across the studied *Kebeles*. Data obtained from the key informant interviews were used to substantiate the result of the household survey.

Relationship between households' perceived outcomes of the CBWM program and their willingness to participate in the program

Spearman's partial correlation coefficients (r_s) were used to determine the influence of farmers' perceived outcomes of the CBWM program on their willingness to participate in the program. This test is more appropriate for ordinal or scale variables that do not satisfy the assumptions of linearity and bivariate normality (Corder and Foreman, 2009). More importantly, it enables the assessment of the net effect of an independent variable on the dependent variable, by controlling the effects of other variables (i.e., control variables). In this study, Spearman's correlation coefficients ($p < 0.05$) were used to select four control variables out of variables that influence farmers' willingness or motivation (Kessler, 2006; Vandersypen et al., 2008). The control variables were (1) households' perception of watershed degradation, (2) households' distance from micro-watersheds, (3) social capital, and (4) performance of *Kebele* administrators. A rule of thumb suggested by Evans (1996) was used to interpret the strength of the correlation coefficient (0.80 to 1.00 (-0.80 to -1.00) very strong positive (negative) correlation; 0.60 to 0.79 (-0.60 to -0.79) strong positive (negative) correlation; 0.40 to 0.59 (-0.40 to -0.59) moderate positive (negative) correlation; 0.20 to 0.39 (-0.20 to -0.39) weak positive (negative) correlation; 0.00 to 0.19 (0.00 to -0.19) very weak positive (negative) correlation).

3.4 Results

This section is divided into three parts. The first part describes the outcomes of the CBWM program (between 2011/12 and 2015/16) focusing on the executed physical works as well as biophysical and socio-economic conditions. The second part presents farmers' perceptions of these outcomes of the program. The last part describes farmers' willingness to participate in the program (in 2015/16).

3.4.1 Outcomes of the CBWM program

Executed physical works

Data obtained through Google Earth Engine show that SWC structures were constructed on 192.17 ha within the studied micro-watersheds (153.61 ha communal land, 38.56 ha farmland) in the past five years. Of this total, 82.61 ha (54.17 ha in Ararso-Bero, 28.44 ha in Sara-Areda) was enclosed and handed over to associations who use, protect, or maintain the structures in the micro-watersheds. Tree seedlings were planted in the enclosed micro-watersheds every year.

SWC structures: During the year preceding this study, stone bunds were constructed in Ararso-Bero and Sara-Areda, mainly on communal land, and soil bunds were constructed in Qachachule-Guja on farmlands. Analysis of Google Earth images taken in April 2016 indicates that some 29.86 km of SWC structures were found on the micro-watersheds that were developed in the past five years, as shown in Table 3.2. However, experts in the District, the supervisor, and extension workers stated that the construction of SWC structures has been below technical standards in almost all localities in the study *Kebeles*. Extension workers particularly stated that the main focus of the program was to mobilize as many farmers as possible to construct a large quantity of SWC structures in a short period of time at the expense of quality. They stated that quality has not been given due attention in reporting achievement and evaluating outcomes since the inception of the program.

Table 3.2 *Lengths of SWC structures (km) in April 2016.*

Kebeles	Year Constructed					Total
	2011/12	2012/13	2013/14	2014/15	2015/16	
Ararso-Bero	2.46	1.73	1.85	3.04	2.29	11.37
Sara-Areda	1.38	0.50	2.26	0.39	1.21	5.74
Qachachule-Guja	1.45	2.15	1.61	1.75	5.79	12.75
Total	5.29	4.38	5.72	5.18	9.29	29.86

Tree seedlings: In order to assess the number of seedlings that were planted in 2015/16, the sample households were asked to estimate the number of seedlings they had planted. Numbers obtained from the sample households were multiplied by the total household population in each *Kebele* and then divided by sample households. Accordingly, it was estimated that a total of 67,841 (31,333 in Ararso-Bero, 35,327 in Sara-Areda, and 1181 in Qachachule-Guja) tree seedlings were planted in the three *Kebeles*. But extension workers, *Kebele* administrators, and leaders of development teams stated that tree seedlings that have been planted since the inception of the program hardly survived. According to the extension workers, this was attributed to incompatibility of the seedlings to the agro-ecological conditions of the *Kebeles*, poor handling of the seedlings during plantation, and absence of proper care after planting the seedlings.

Change in biophysical conditions

The program generated some short-term (e.g. runoff control and moisture retention) and medium-term (e.g. vegetation cover and soil fertility improvement) biophysical outcomes.

Short-term outcomes: According to leaders of development teams and village elders in Ararso-Bero, stone bunds have reduced runoff on communal lands and adjacent farmlands. They also stated that this indeed has contributed to moisture retention, particularly on farmlands. However, the informants were concerned about frequent runoff from upstream neighboring *Kebeles*. Similarly, for leaders of development teams, extension workers, and village elders in Sara-Areda, the program has substantially contributed to runoff control and moisture retention in and around the micro-watersheds on communal land. In Qachachule-Guja, however, extension workers and leaders of development teams indicated that the contribution of the program to runoff control on communal land has been quite limited because of the complete destruction of the SWC structures and planted tree seedlings. They related this to severe runoff water coming down from neighboring *Kebeles*, and yet absence of maintenance and conservation practices.

Medium-term outcomes: An improvement of vegetation cover was one of the medium-term outcomes revealed by the key informants. In Ararso-Bero and Sara-Areda, leaders of development teams and village elders noted that the barren land has changed into green vegetation in micro-watersheds that were successfully enclosed. They related this change to the regeneration of natural species. The informants also stated that vegetation cover improved weather conditions and precipitation around the micro-watersheds, attracted wild animals, and enhanced the availability of grasses and woods. Data obtained through Google Earth Engine indicates that the coverage of grassland was reduced while the coverage of forestland was increased in Ararso-Bero. This was opposite in Sara-Areda, as shown in Figure 3.2. In Qachachule-Guja, all key informants stated that the program has had very limited contribution to the improvement of vegetation cover. Particularly, extension workers stated that the program has exacerbated land degradation because of the increased competition among farmers to use and/or fence off a portion of the micro-watersheds. But as seen in Figure 3.2, the coverage of forestland increased, most probably because farmers who fenced off portions of the micro-watersheds were better conserving the land.

The other important medium-term outcome revealed by the key informants was soil fertility improvement. In Ararso-Bero, the extension workers, leaders of development teams, and village elders highlighted an improvement of soil fertility on farmlands that are adjacent to the communal lands. They cited an improvement of crop productivity (e.g. sorghum) on plots where the bunds constructed effectively controlled runoff. Some village elders particularly stated that the productivity of such plots is comparable to those treated by fertilizers. Similarly, village elders and leaders of development teams in Sara-Areda reported a visible difference between farmlands with and without SWC structures in terms of crop productivity. They noted that bunds enhance crop productivity by keeping seeds and fertilizers from being washed away by runoff water. In Qachachule-Guja, all informants saw limited contribution of the program to soil fertility improvement since most SWC structures and planted tree seedlings were destroyed.

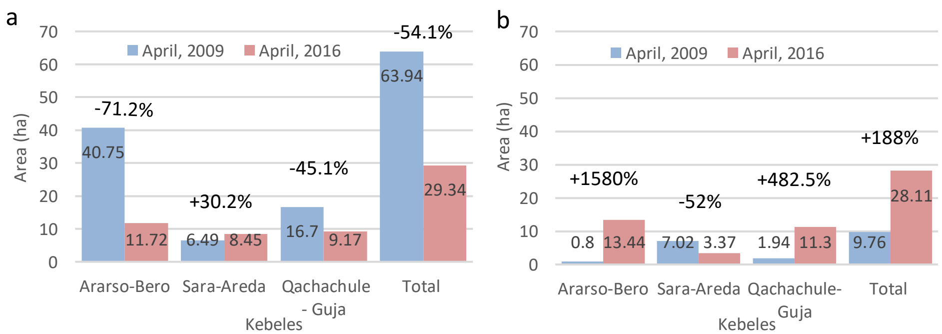

Figure 3.2 Percentage change in vegetation cover: (**a**) grassland; (**b**) forestland.

Change in socio-economic conditions

The key informants identified some immediate positive and negative socio-economic outcomes of the CBWM program.

Conflicts among farmers: Conflicts between farmers who live in the vicinity of the micro-watersheds and micro-watershed associations were frequently mentioned as an undesirable outcome of the program. For instance, extension workers and leaders of development teams stated that farmers' protests against area closure in the Qawa-Qeransa micro-watershed led to the destruction of SWC structures in Ararso-Bero. In Sara-Areda, in 2014/15, violent conflicts between a youth association and a micro-watershed association for ownership of a micro-watershed led to the destruction of growing tree seedlings by the former. In Qachachule-Guja, protest by farmers living in the vicinity of micro-watersheds was the main factor for the absence of area closure and micro-watershed associations.

Access to communal land and income earnings: Farmers in the vicinity of micro-watersheds oppose area closure mainly because they perceived this will dwindle their access to open grazing on communal land. However, in Ararso-Bero and Sara-Areda, village elders and extension workers stated that access to communal land increased for members of micro-watershed associations, who usually get some animal forage/grass or cash income from sale of grasses. This was completely lacking in Qachachule-Guja. Even though an attempt for area closure completely failed in Qachachule-Guja, access to communal land reduced for some farmers and increased for others since some farmers fenced off portions of the micro-watersheds for their private use.

Knowledge and skills: Most key informants in the three *Kebeles* mentioned the substantial contribution of the program to the knowledge and skill development of the farmers. Leaders of development teams particularly stated that most farmers came to know how to construct SWC structures only after the introduction of the program. As a result, according to extension workers, some farmers have already started constructing SWC structures on their own farmlands.

3.4.2 Farmers' perceptions of outcomes of the CBWM program

In order to assess farmers' perception of outcomes of the CBWM program, factor analysis was used to identify 11 factors, out of the original 15 factors considered. The other four factors were discarded due to either their low value of factor loadings (<0.4) or cross-loading, as shown in Table 3.3. The factor analysis extracted three latent variables or factors which we labeled physical effects, effects on personal capacities, and economic effects. These factors together explained 74.05% of the total variance in the dataset. The first factor - physical effects - encompasses farmers' perceptions of quality of SWC structures and planted tree seedlings, and their biophysical outcomes. It accounts for the highest variance in the dataset (48.90%). The second factor - effects on personal capacities - involves farmers' perceived effects of the program on their skills and acceptance of SWC structures. The third factor - economic effects - involves farmers' perceived access to communal land and income obtained from the program.

Table 3.3 *Rotated component matrix of outcome indicators for the three Kebeles (n = 275).*

No.	Households' Perceived Outcomes	Extracted Factors		
		Physical Effects	Effects on Personal Capacities	Economic Effects
1	Quality/proper construction of SWC structures	0.804		
2	Compatibility/appropriateness of planted tree seedlings	0.802		
3	Survival of planted tree seedlings	0.792		
4	Effect on runoff control	0.899		
5	Effect on moisture retention	0.897		
6	Effect on vegetation cover	0.892		
7	Effect on soil fertility improvement	0.937		
8	Obtained skills		0.857	
9	Constructing SWC structures on their land on their own		0.786	
10	Access to communal land			0.730
11	Income			0.845
Explained variance (%)		48.90	14.03	11.12

The factor analysis was followed by calculating scores that represent each extracted latent variable or factor (physical effects score, effects on personal capacities score, economic effects score) and the overall farmers' perceived outcomes of the CBWM program (households' perceived outcome score). On the scale that ranges between 0 and 2, the average farmers' perceived outcome score was 0.73, as shown in Table 3.4. This score indicates that farmers' appreciation of the outcomes of the program was quite low. Across the study *Kebeles*, the score was highest in Sara-Areda and lowest in Qachachule-Guja.

Table 3.4 *Mean scores of households' perceived outcomes of the CBWM program (0 = lowest, 2 = highest).*

Factors	Ararso-Bero (n = 105)	Sara-Areda (n = 110)	Qachachule-Guja (n = 61)	All *Kebeles* (n = 276)	F Value
Physical effects	1.15	1.63	0.43	1.16	390.61 ***
Effects on personal capacities	0.47	0.72	0.67	0.62	13.44 ***
Economic effects	0.58	0.14	0.47	0.40	62.92 ***
Mean	0.74	0.84	0.52	0.73	65.76 ***

*** $p < 0.01$

Farmers' perceptions of the physical effects of the program was relatively higher. Farmers particularly held positive opinions of the contribution of the program to the improvement of biophysical conditions of their farmland and communal land they accessed, as shown in Table 3.1. This was highest in Sara-Areda and lowest in Qachachule-Guja. As indicated under Section 3.4.1, the exposure of micro watersheds both in Ararso-Bero and Qachachule-Guja to runoff water from neighboring *Kebeles* negatively influenced farmers' perceived physical effects of the program. This was particularly important in Qachachule-Guja, where collective maintenance and conservation practices were completely lacking.

Farmers also perceived that the program has somewhat improved their personal capacities through the development of their skills on how to construct SWC structures and enhancing their capabilities to implement the structures on their land on their own. Across the studied *Kebeles*, this perception was relatively higher in Sara-Areda and lowest in Ararso-Bero. The relatively lower score in Ararso-Bero and Qachachule-Guja may be related to the inability of some farmers to implement the skills they learned on their land since they were busy with off-farm and non-farm activities, respectively.

Furthermore, farmers indicated that the economic effects of the program in terms of improving access to communal land and income earnings was quite limited. This was particularly low in Sara-Areda. The reason could be lower income earned by members of the micro-watersheds in Sara-Areda as compared to Ararso-Bero. Though micro-watershed associations were absent in Qachachule-Guja, access to communal land has improved for some farmers because of the failure of area closure initiatives and thus open access to the micro-watersheds.

3.4.3 Farmers' willingness to participate in the CBWM Program

In order to assess the willingness of farmers to participate in the CBWM program, seven items each measured on a scale from 0 to 3 were used to calculate total households' willingness scores. On the scale that ranges between 0 and 21, the mean households' willingness score was 15.74.

As indicated in Table 3.5, the most important items that revealed farmers' willingness to participate in the CBWM program were their perceptions of the usefulness of training given before campaign works, belief that the CBWM program could contribute to ecosystem restoration or livelihood improvement, and approval of the construction of SWC structures on their farmland and communal land they use. These three items indicate that farmers were more motivated to undertake training to improve their knowledge and skills on activities that were implemented during campaign works and support the construction of SWC structures on their farmland and the communal land they use because they believed that these will benefit them.

Table 3.5 *Mean households' willingness score to participate in the CBWM program.*

No	Indicators	Ararso-Bero	Sara-Areda	Qachachule-Guja	Mean	F Value
1	Usefulness of trainings given before campaign works	2.39	2.61	2.51	2.50	5.94 ***
2	Belief that the CBWM program contributes to ecosystem restoration or livelihood improvement	2.45	2.48	2.46	2.46	0.09
3	In favor of the construction of SWC structures	2.45	2.17	2.02	2.24	17.91 ***
4	Willingness to contribute labor for campaign works	2.07	2.41	2.09	2.19	18.73 ***
5	Willingness to use own working tools	1.97	2.35	2.12	2.14	23.42 ***
6	Own initiative to participate in the CBWM program	2.14	2.14	2.15	2.14	0.01
7	Willingness to maintain and protect the micro-watersheds	2.02	2.39	1.43	1.99	75.59 ***
Total (0 = lowest, 21 = highest)		15.50	16.57	14.91	15.74	14.28 ***

*** $p < 0.01$

However, the mean scores for farmers' own initiative to participate in the CBWM program, contribute labor to campaign works, use own working tools during campaign works, and maintain and protect the micro-watersheds was relatively lower. These four items show that farmers were less motivated to contribute labor and materials without pressure from local government actors. Hence, it is important to understand conditions that motivate farmers to participate in the program. Leaders of development teams and village elders suggested some specific conditions that could motivate farmers to participate in the program: (1) proper recognition for farmers' labor contribution during campaign works (e.g. certificates, awards, financial incentives), (2) compensation for farmers' working tools when broken in the field during campaign works, and (3) minimizing bias in the selection of members while establishing new micro-watershed associations.

Across the studied *Kebeles*, the total mean score was highest in Sara-Areda and lowest in Qachachule-Guja. Table 3.5 shows also that the score for all items was higher in Sara-Areda, except for "in favor of the construction of SWC structures". Another observation is that the lowest score (1.43) in Table 3.5 refers to "farmers' willingness to maintain and protect the micro-watersheds" in Qachachule-Guja, which is due to the failure of the area closure initiative in this *Kebele*. However, there was no difference between the three *Kebeles* with regard to farmers' belief about the possible contribution of the program to ecosystem restoration or livelihood improvement and own initiative to participate in the program.

3.5 Discussion

The main objective of this study was to assess farmers' perception of the outcomes of the Campaign-Based Watershed Management (CBWM) program in Ethiopia, and how this influences their willingness to participate in the program in Boset District, Ethiopia. To this end, Spearman's partial correlation coefficient (r_s) was used between the scores that represent farmers' perceived outcomes of the program and their respective willingness score. The result shows that there was a statistically significant positive (but very weak) relationship between total households' perceived outcome score and willingness score. This indicates that prior outcomes of the CBWM program hardly motivated farmers to participate in the program. But this relationship was not found for each study *Kebele* separately, as shown in Table 3.6.

Table 3.6 *Spearman's partial correlation coefficients (r_s) of households' perceived outcome scores and willingness score.*

Outcome Scores	Farmers' Willingness Score			
	Ararso-Bero	Sara-Areda	Qachachule-Guja	All Kebeles
Physical effects	−0.059	0.142	−0.056	−0.109
Effects on personal capacities	0.260 ***	−0.044	−0.079	0.292 ***
Economic effects	0.056	0.037	0.110	0.078
Total outcomes	0.103	0.066	0.065	0.171 ***

*** $p < 0.01$

Of the studied latent variables or factors, no correlation was found between farmers' perceived physical effects score and willingness score for all *Kebeles* together and each separately, as shown in Table 3.6. The absence of influence of physical effects on the willingness of farmers could be attributed to the limited direct biophysical benefits of the program to most individual households since the intervention has been mainly confined to selected micro-watersheds on communal lands both in Ararso-Bero and Sara-Areda. This is consistent with other studies in Ethiopia that indicate that farmers are less motivated to participate in an initiative (Agidew and Singh, 2018) or adopt conservation technologies (Amsalu and de Graaff, 2006; Zeweld et al., 2018) that will not generate short-term benefits at a farm household level. In addition, in some micro-watersheds, SWC structures and planted tree seedlings were being destroyed by flood water coming down from upstream neighboring *Kebeles*, particularly in Ararso-Bero and Qachachule-Guja. Furthermore, micro-watersheds were generally exposed to human and animal disturbances in all *Kebeles*, which exacerbates erosion problems (Amsalu and de Graaff, 2006) and creates a sense of apathy among farmers (Bagherian et al., 2009). This was particularly important in Qachachule-Guja, where farmers were demotivated by the total absence of area closure and thus maintenance and protection of the micro-watersheds on communal land since the inception of the program.

However, a relatively strong relationship was found between farmers' perceived effects on their personal capacities score and willingness score in all *Kebeles* together and in Ararso-Bero, as shown in Table 3.6. This shows skills that farmers obtained on how to construct SWC structures and implementation of the structures have motivated them to participate in the program. This could be because some farmers in Ararso-Bero cultivate steep plots compared to other *Kebeles*. On steeper slopes, soil erosion problems are generally more severe than on relatively gentle ones. These erosion problems possibly improved farmers' flood perception and stimulated them to learn skills on how to construct SWC structures (Teshome et al., 2016a) and start constructing the structures on their own farmlands (Amsalu and de Graaff, 2006; Kessler, 2007; Abi et al., 2018b). Such farmers are generally more dynamic and intrinsically motivated to participate in other collective action initiatives, including the CBWM program. Though farmers in Qachachule-Guja experienced erosion problems and had higher flood perception, they were not motivated by the effect of the program on their personal capacities (see Section 3.4.1). One possible reason for this is failure of previous micro-watershed (communal lands) management, which discouraged farmers in participating in the program. The other reason may be that farmers who live both in Bofa town and rural neighborhoods are generally less motivated to participate in the program, since they focus on their non-farm activities in the town (Assefa et al., 2018a). Similarly, although farmers obtained skills and started constructing SWC structures on their farmlands in Sara-Areda, these did not motivate them to participate in the program because they generally cultivate relatively flat plots that are less exposed to erosion problems.

Finally, farmers' perceived economic effects score was not correlated with willingness score for all *Kebeles* together and each one separately, as shown in Table 3.6. One possible reason for this was the absence or weakness of micro-watershed associations to manage treated micro-watersheds. According to Assefa et al. (2018a), micro-watersheds have been handed over to associations that were not real target groups in Ararso-Bero and Sara-Areda. This explicitly excludes non-members from any short-term economic benefits, demotivates these non-members to participate in the program, and contributes to unequal access to resources. Even so, the associations rarely ensure maintenance and conservation of the micro-watersheds, which might have driven members to question the plausibility of the associations, sustainability of the micro-watersheds, and continuity of some economic benefits they were receiving. Unlike other *Kebeles*, which at least handed over the micro-watersheds to associations, a clear benefit-sharing mechanism was lacking in Qachachule-Guja. This not only discouraged farmers to participate in the program, but also served as a potential source of conflict, as indicated by Nigussie et al. (2018). The other reason could be conflicts among farmers over access to communal land, since area closures and the handing over of the micro-watersheds to associations reduces access to communal land for some farmers, while it increases access for others. For instance, in Qachachule-Guja, not a single micro-watershed was handed over to associations due to farmers' protest against area closure. Conflicts among farmers abate social cohesion, mutual trust, social networks, and weaken their motivation to participate in the CBWM program and other similar collective action initiatives.

3.6 Conclusions

The main objective of this study was to assess farmers' perception of the outcomes of the Campaign-Based Watershed Management (CBWM) program in Ethiopia and how this influences their willingness to participate in the program. Data obtained from key informants and Google Earth Engine show that the construction of Soil and Water Conservation (SWC) structures, planting tree seedlings, and area closures have improved biophysical and socio-economic conditions in the study area. However, farmers' perceived outcomes of the program hardly motivated them to participate in the program. Particularly, physical effects of the program as perceived by the farmers demotivated them to continue participating in the program. This was especially due to the limited direct biophysical benefits of the program to farm households, and the destruction of previously developed micro-watersheds by frequent runoff from neighboring *Kebeles* and human and animal disturbances. Similarly, farmers were not motivated by the economic effects of the program, because of the limitations/absence of benefit-sharing mechanisms and resultant conflicts among farmers. Where micro-watersheds were handed over to associations, their appropriateness was debatable. Where they were absent, questions remained as to how the future accrued benefits will be shared among farmers. The only motivating outcome of the program concerned its effect on personal capacities, which was particularly appreciated in localities that were vulnerable to erosion. This means farmers who obtained skills on how to construct SWC structures and those who started constructing SWC structures on their own farmlands were more motivated to participate in the program.

Hence, in order to enhance the willingness of farmers to genuinely participate in the CBWM program, three recommendations are drawn from the above results: (1) better integrate actions at watershed level to come to effective water runoff control and collaboration between neighboring villages in watersheds, (2) enhance the participation of all local actors to come to more effective area closure initiatives with transparent benefit-sharing mechanisms for equitable distribution of the outcomes of the program, and (3) give much more emphasis to capacity building as a cross-cutting component in the program since this ensures short-term biophysical benefits to individual farm households as well as motivates them to participate in the program. These recommendations suggest that the program should use a more participatory and integrated approach to motivate farmers and enhance their genuine participation. In this regard, future research should focus on exploring a more sustainable collective watershed management strategy through discussions, negotiations, and learning among local actors.

4. Exploring decision-making in campaign-based watershed management by using a role-playing game in Boset District, Ethiopia

This study uses a Role-Playing Game (RPG) to analyze farmers' decision-making in Campaign-Based Watershed Management (CBWM) program, and learning and collective decision-making among local actors in Boset District - Ethiopia. Results show that farmers prefer to collectively work on private farmlands rather than on communal land. Furthermore, participation of farmers in campaign works was higher under a default-scenario (with control instruments), than under a willingness-scenario (without control instruments). In making decisions on their level of participation, farmers followed the decisions of a fellow farmer they considered more knowledgeable. However, the participation of farmers in the maintenance of Soil and Water Conservation (SWC) structures was more or less the same under both scenarios. Both farmers' level of participation in campaign works and maintenance decisions were influenced by their location or proximity to the CBWM intervention areas (i.e. micro-watersheds to be treated) as well as their awareness and motivation. The commitment of local government actors was also crucial to enforce and encourage the farmers to participate in the program. Based on farmers' decisions in the RPG, none of the two scenarios simultaneously enhance the total land area covered with SWC structures and income of farmers. An important benefit of this game was that it stimulated mutual learning and collective decisions on micro-watersheds to be treated and alternative management strategies for the CBWM program. This revealed that there is a need to (1) motivate farmers through capacity building, (2) enhance the commitment of local government actors, and (3) introduce participatory planning to enhance mutual learning and collective decisions for sustainable watershed management.

Based on:

Assefa, S., Kessler, A. and Fleskens, L. 2020. Exploring decision-making in campaign-based watershed management by using a role-playing game in Boset District, Ethiopia. Agricultural systems (submitted).

4.1 Introduction

With the introduction of the participatory integrated watershed management approach in the 1990s, more participatory, demand-driven, and decentralized interventions have been promoted in developing countries (Darghouth et al., 2008). In Ethiopia, this approach has been central to non-project based interventions that have been carried out through campaign works since the 1990s. In 2011/12, the government initiated the national Campaign-Based Watershed Management (CBWM) program that has been implemented at the *Kebele* (village) levels with the mass mobilization of farmers, coordination of *Kebele* administrators and leaders of development teams, and technical support of extension workers (Danano, 2010; Wolancho, 2015; Haregeweyn et al., 2015).

The program entails the implementation of Soil and Water Conservation (SWC) structures both on communal land and private farmlands in one or two selected micro-watershed/s (the intervention units for the CBWM program) for 30 to 40 days annually (Wolka, 2014). In terms of farmers' labor contribution and area of land covered with SWC structures, the CBWM program has been regarded successful (Haregeweyn et al., 2015). However, the program has a number of limitations, including a top-down planning approach (Snyder et al., 2014; Nigussie et al., 2018; Assefa et al., 2018a), low awareness and willingness of farmers to participate in the program (Abi et al., 2019; Assefa et al., 2018a), poor commitment of local government actors (Assefa et al., 2018a), emphasizing the construction of SWC structures rather than paying attention to rural livelihoods (Wolka, 2014; Assefa et al., 2018a), and poor maintenance of the SWC structures (Snyder et al., 2014; ORAB, 2014; Wolancho, 2015).

These limitations suggest the need to focus the analysis of the CBWM program on the process of farmers' decision-making and explore alternative collective watershed management strategies. Participatory approaches (e.g. Participatory Rural Appraisal, Participatory Action Research) have been used to analyze such research problems (Sturdy et al., 2008). Though these approaches are effective in enabling local communities to conduct their own analysis of a particular problem and take action (Chambers, 1992), they don't permit farmers to explore outcomes of their decisions and learn from this process.

Role-Playing Games (RPGs) have been effectively used in the context of natural resource management to (1) understand actors' decision-making behavior (e.g. Castella et al., 2005; Pak and Brieva, 2010), (2) explore possible scenarios (e.g. Pak and Brieva, 2010), and (3) enhance discussions and negotiations among actors (e.g. Castella et al., 2005; Souchère et al., 2010). Most of these games are open-ended in which goals and rules have many degrees of freedom and therefore the solution space of the game is mostly unknown (Speelman et al., 2014). Such games are difficult to reproduce and systematic comparison of results is often limited (Bousquet et al., 2002). In closed games, goals and rules define a large but countable set of solutions (Speelman et al., 2014; Michalscheck et al., 2020). Hence, these games can be used in an experimental setup that allows replication of results with various groups (Falk and Heckman, 2009; Janssen et al., 2010) and testing of specific experimental hypotheses about the relation between game outcomes, and the attributes and behaviors of players (Janssen, 2010; García-Barrios et al., 2011). They could therefore be crucial for our case to simulate how farmers make decisions by interacting with other actors in the CBWM program and how this affects the outcomes of the program. However, to our knowledge, closed RPGs are hardly used in the context of collective watershed management decisions.

This study therefore developed a RPG based on empirical studies conducted on the CBWM program (Assefa et al., 2018a; Assefa et al., 2018b) and subsequent pilot sessions in the Boset District. The game requires farmers to choose between advancing their individual interests (income) and collective interests (participate in the program). The main objectives of this paper are to (1) assess farmers' decision-making, focusing on how the decisions of farmers to engage in the CBWM program are influenced by their own attributes and their interactions with other actors, and (2) facilitate discussions and mutual learning among actors to make collective decisions on alternative watershed management strategies in three *Kebeles.* The game is played using two scenarios, each having five time steps or years: (1) a *default-scenario* or current condition - where *Kebele* administrators encourage (using awareness creation) and enforce (using control instruments such as reprimanding and punishing) farmers to participate in the program, and (2) a *willingness-scenario* - where the role of *Kebele* administrators is limited only to awareness creation without control instruments.

4.2 Materials and methods

4.2.1 Study area

The CBWM program has been implemented in all 33 rural *Kebeles* of Boset District. This section discusses the implementation of the program in Ararso-Bero, Sara-Areda, and Qachachule-Guja *Kebeles* that were selected based on their difference in levels of performance in the CBWM activities (BDAO, 2015). They are adjacent and together cover a total area of 10,669 ha; where Ararso-Bero, Sara-Areda, and Qachachule-Guja constitute 2760 ha, 3913 ha, and 3996 ha respectively (BDAO, 2015).

The CBWM program has three key activities or phases: (1) selecting one or more micro-watersheds to be developed, (2) constructing SWC structures and planting tree seedlings in the selected micro-watersheds through campaign works, and (3) enclosing and handing over the micro-watersheds that are located on communal land and private farmland to associations and individual owners respectively so that they protect or maintain conservation measures (Assefa et al., 2018b). These activities are implemented with the involvement of extension workers, *Kebele* administrators, leaders of development teams (also sometimes leaders of micro-watershed associations), and the farmers; each having their own roles and responsibilities.

Since the inception of the program, four micro-watersheds were developed (i.e. the first two phases completed) in Ararso-Bero while five micro-watersheds were developed in Sara-Areda and Qachachule-Guja. According to Assefa et al*.* (2018b), 192 ha of land (154 ha communal land, 39 ha farmland) has been covered with conservation measures in these *Kebeles*. Of this total, 82.6 ha (54.2 ha in Ararso-Bero, 28.4 ha in Sara-Areda) has been put under area closure and handed over to micro-watershed associations. In Qachachule-Guja, not a single micro-watershed on communal land was handed over to micro-watershed associations and area closure initiatives are lacking.

4.2.2 Description of the RPG

Actors

For the purpose of this study, twelve local actors were invited to play the RPG at each study *Kebele*: one extension worker, one *Kebele* administrator, one leader of the development team/micro-watershed associations, and nine farmers. The farmers are further clustered into wealth (three rich, three moderate, and three poor), distance from micro-watersheds (three near, three somewhat far, and three far), and membership in a micro-watershed association (three members and six non-members) subgroups. The actors were selected based on their actual roles and responsibilities in the CBWM program. The roles and responsibilities of the actors in the game are described in Table 4.1. In this game, farmers are the most important actors and they make trade-offs between advancing their individual interests (maximize their income) and collective interests (participate in the program). In this regard, the main goal of a farmer is to win the game by accumulating more cash money at the end of the game session.

Table 4.1 *Actors and their roles and responsibilities.*

Actors	Roles and responsibilities	Depends on
Farmers	Select new micro-watershed for collective action by marking their preferred location on the map. Make a decision on their level of participation in campaign works (0 = no participation, 10 = highest participation). Make maintenance decisions by selecting either “maintain”, “ignore” or “demolish” options.	Farmers’ own attributes, interaction among farmers, and interaction with other actors
Leader of development team	Motivates farmers to participate in campaign works and maintenance of SWC structures. Monitors attendance during campaign works and maintenance decisions. Reports names of farmers whose participation is lower to *Kebele* administrators. Distributes cash money to members of micro-watershed associations when area of land covered with SWC structures increases.	Commitment of *Kebele* administrator
Extension worker	Discusses and negotiates with farmers during the selection of new micro-watersheds. Gives feedback to actors at the end of each time step.	No specific conditions or rules*
Kebele administrator	Orders famers to make decisions on their level of participation in campaign works and maintenance decisions. Take measures (“aware”, “reprimand”, “punish”) based on farmers’ level of participation in campaign works and maintenance decisions. Establishes new associations and handover newly developed micro-watersheds on communal land to the associations.	No specific conditions or rules*

* The actors are invited to make their own preferred decisions to assess conditions that influence their decisions

The first author of the paper acted as moderator of the RPG and was assisted by the game facilitator. All game sessions were videotaped by a camerawoman for further analysis.

Materials

This game is conducted by using the following materials.

- Map or game board showing the location of previous micro-watersheds, land use (farmland vs communal land), slope, and homesteads of farmers.
- Cards showing newly selected micro-watersheds and micro-watersheds already covered with SWC structures.
- Cards showing initial attributes of each farmer: distance from nearest micro-watersheds (static), membership in one of the micro-watershed association (static), wealth status (dynamic), and ownership of farmland (static).
- Fake money for each farmer representing their wealth status: 1500 birr for the rich, 1000 birr for middle income, and 500 birr for poor farmers.
- 11 white squared cards (0 to 10) for each farmer, representing farmer’s level of participation in campaign works.
- Three squared cards for each farmer, representing farmer’s maintenance decisions: “Maintain” (green), “Ignore” (yellow), and “Demolish” (red).
- Three triangle cards representing measures taken by *Kebele* administrator: Green (aware), Yellow (Reprimand), and Red (Punish).

- Two small boxes, where farmers drop cards that best reflect their decisions: level of participation in campaign works and maintenance decisions.

Game procedure

The game has three stages: preparation (20 minutes), playing (50 minutes * 5 time steps), and debriefing (30 minutes). At the preparation stage, the moderator presents previous outcomes of the CBWM program to motivate the actors to actively participate in the game sessions. He then introduces the objectives of the game sessions, and roles and responsibilities of each actor in the game (*see* appendix 1.1). This is followed by a detailed description of the game procedures to the actors by the moderator and facilitator to ensure that all actors understand game procedures, their roles and responsibilities, and consequences of their decisions. The actors are then invited to reflect on the relationship between their actual roles and responsibilities, and those introduced in the game. At the playing stage, farmers are invited to make decisions on the location of new micro-watersheds, level of participation in the campaign works, and maintenance of SWC structures (*see* appendix 1.2). The actors are formally invited to reflect on the implementation and outcomes of the game at the debriefing stage, but spontaneous discussions and negotiations among actors are encouraged right from the beginning of the game sessions.

Estimation of farmers' decision scores and outcomes

The decisions of each farmer are used to estimate two average scores: *campaign score* and *maintenance score*. The campaign score is calculated based on individual farmer's level of participation in campaign works at each time step (*see* appendix 1.3). It ranges between 0 and 10 and each unit is estimated to be equal to three work days. This means a campaign score of 10 is equal to 30 days of participation in campaign works. Similarly, the maintenance score is calculated by transforming farmer's decisions, i.e. "maintain", "ignore", or "demolish" to an average score that ranges between 0 and 10 (*see* appendix 1.3). The "maintain" decision is assigned a weight of 10 with the decision to keep SWC structures as they are; while the "ignore" decision is assigned a weight of 5 to indicate a modest decline in area of land covered with SWC structures. The "demolish" decision is assigned a weight of 0 to indicate the complete destruction of SWC structures.

The decisions of farmers result in collective outcomes (area of land covered with SWC structures) and individual outcomes (income). The area of land covered with SWC structures (ha) at each time step is derived from the total lengths of SWC structures that is calculated based on existing lengths of SWC structures in the micro-watersheds, lengths of SWC structures constructed through campaign works, and maintenance scores (*see* appendix 1.3). Similarly, the average income (birr) of farmers at each time step is a function of farmers' initial wealth status, participation level in campaign works, maintenance decisions, and income from SWC structures (*see* appendix 1.3).

4.2.3 Monitoring and analysis scheme

Data collection

The game was implemented in the three study *Kebeles* in 2017/18. In order to collect relevant data during the game sessions, *observation of farmers' behavior* was conducted by using recorded videos to assess factors influencing their decisions as well as patterns of interactions among the actors. *Group discussions* were also employed during the preparation, playing, and debriefing stages of the game. During the preparation stage, discussions were held on the previous outcomes of the program and roles and responsibilities of actors. At the playing stage, discussions were held to initiate learning and collective decision-making on the location of new micro-watersheds to be developed. Group discussions were mostly held at the debriefing stage to identify factors influencing farmers' decisions, initiate learning, and explore collective alternative watershed management strategies.

Data analysis

Farmers' decision-making: Descriptive statistics were used to analyze farmers' decisions (campaign works, maintenance of SWC structures), the effect of farmers' own attributes on their decisions (wealth status, distance from micro-watersheds, membership in micro-watershed associations), and interactions among actors (e.g. influence of *Kebele* administrator on the decisions of farmers, relationships among farmers). In addition, qualitative analysis was employed to assess the decisions of farmers during the selection of new micro-watersheds, and to further explore factors influencing farmers' decisions, and interactions among actors (e.g. relationships between extension workers and farmers' decisions).

Game outcomes, learning, and collective decision-making: Descriptive statistics were used to analyze the collective outcomes (area of land covered with SWC structures) and individual outcomes (income) of the game sessions, as well as to examine learning among actors by assessing patterns of change of farmers' decisions overtime. Qualitative analysis of group discussions was employed to explore learning and collective decisions on the new micro-watersheds to be developed and alternative watershed management strategies.

4.3 Results

4.3.1 Preparation stage

The moderator firstly gave a presentation on the actual status of the CBWM program, focusing on lengths of SWC structures and area of land covered with SWC structures. The *Kebele* administrators, leaders of development teams, and some farmers regarded these outcomes to be very meagre, particularly in Ararso-Bero and Sara-Areda. For instance, the *Kebele* administrator in Ararso-Bero stated that "what you presented here [outcomes of the program] is not even comparable with what we usually do in the first five or six days every year". Explanation was given by the moderator (on how the outcomes were estimated) and extension worker (possible reasons for the difference between farmers' expectation and the outcomes presented by the moderator). After thorough discussions, the actors agreed that some SWC structures might have been destroyed because of poor conservation practices and flooding in the past five years. There was also a mutual agreement among the actors on the limitations of how they estimate the outcomes and the problem of exaggerating the outcomes to please government authorities. This discussion contributed to the creation of trust between the moderator and the actors to openly express their views regarding the limitations of the program and suggest alternative management options at the playing and debriefing stages.

In addition, the presentation given by the moderator on the objectives of the game sessions, and roles and responsibilities of the actors in the game and subsequent detailed description of the game procedures enabled the actors to understand the nitty-gritty of the game. Consequently, the game participants asserted that the game actually mimics activities that they carry out in the program.

4.3.2 Playing stage

Farmers' decisions

Farmers were invited to make decisions on the location of new micro-watersheds for collective action, level of participation in campaign works, and maintenance of SWC structures. Farmers were asked by the extension worker to mark their preferred location of new micro-watersheds on a map or game board at the beginning of each time step. In all the *Kebeles*, farmers at each time step preferred to collectively work on private farmlands located in the downstream areas, rather than at the communal lands located in the upstream part of the watersheds. The decisions of farmers were followed by discussions among actors to collectively decide on the location of new micro-watersheds. In Ararso-Bero and Qachachule-Guja, all actors followed the decision of the farmers by opting for private farmlands in all the five time steps, although they were aware of the importance of developing other upstream communal lands before proceeding to the downstream private farmlands. However, in Sara-Areda, after discussions and negotiations, the actors collectively decided to develop private farmlands only at the 1st and 5th time steps. In order to make a fair comparison, the micro-watersheds selected while playing the game under the *default-scenario* were also used under the *willingness-scenario*.

Farmers also decided on their level of participation in campaign works by selecting a number that best represents their level of participation at each time step. As shown in Table 4.2, under the *default-scenario*, the average campaign score was highest in Ararso-Bero (7.2) and lowest in Qachachule-Guja (6.1). However, under the *willingness-scenario*, the average campaign score was highest in Sara-Areda (5.5) and lowest in Ararso-Bero (4.5). In general, the comparison between the *default-scenario* and *willingness-scenario* shows that participation in campaign works is higher under the current condition where *Kebele* administrators require farmers to contribute labor through coercive measures or control instruments, rather than under the scenario where farmers are invited to participate willingly.

Table 4.2 *Farmers' campaign score (0 to 10) for initial wealth status, distance, and membership in micro-watershed associations.*

		Initial wealth status (birr)			Distance			Membership in micro-watershed associations		Average
Kebeles	Scenarios	1500	1000	500	Near	Somewhat far	Far	Member	Non-member	
Ararso-Bero	Default-scenario	7.7	7.3	6.7	8.5	7.4	5.8	8.4	6.7	7.2
	Willingness-scenario	4.9	4.5	4.0	6.6	4.3	2.6	6.3	3.6	4.5
Sara-Areda	Default-Scenario	6.8	7.5	6.8	8.4	7.3	5.4	8.4	6.3	7.0
	Willingness-scenario	5.3	5.9	5.3	6.8	5.5	4.2	6.9	4.8	5.5
Qachachule-Guja	Default-scenario	6.1	6.3	5.9	7.1	6.3	4.7	-	-	6.1
	Willingness-scenario	4.8	5.3	4.5	6.1	4.7	3.7	-	-	4.8
All Kebeles	Default-scenario	6.9	7.0	6.5	8.0	7.0	5.3	8.4	6.5	6.8
	Willingness-scenario	5.0	5.2	4.6	6.5	4.8	3.5	6.6	4.2	4.9

Lastly, farmers were asked to make maintenance decisions on the already developed micro-watersheds by choosing among "maintain", "ignore" or "demolish" options at each time step. Table 4.3 shows that maintenance scores were more or less the same under the *default-scenario* and *willingness-scenario* in all *Kebeles*. This means that the absence of control instruments by *Kebele* administrators under the *willingness-scenario* didn't considerably change farmers' *maintenance score* and playing the game in the absence of these measures hardly changed the decision of farmers. Across the *Kebeles*, the scores were highest in Ararso-Bero and lowest in Qachachule-Guja under both the *default-scenario* and *willingness-scenario*.

Table 4.3 *Farmers' maintenance score (0 to 10) for initial wealth status, distance, and membership in micro-watershed associations.*

		Initial wealth status (birr)			Distance			Membership in micro-watershed associations		Average
Kebeles	Scenarios	1500	1000	500	Near	Somewhat far	Far	Member	Non-member	
Ararso-Bero	Default-scenario	10.0	9.0	7.0	10.0	8.7	7.3	10.0	8.0	8.7
	Willingness-scenario	8.0	9.7	8.0	10.0	8.3	7.3	10.0	7.8	8.7
Sara-Areda	Default-scenario	6.0	9.0	5.0	8.3	6.0	5.7	9.3	5.3	6.7
	Willingness-scenario	5.0	8.7	6.7	9.0	6.0	5.3	10.0	5.2	6.8
Qachachule-Guja	Default-scenario	7.0	6.3	5.0	7.3	6.3	4.7	-	-	6.1
	Willingness-scenario	7.0	6.7	5.0	8.3	5.3	5.0	-	-	6.2
All Kebeles	Default-scenario	7.7	8.1	5.7	8.5	7.0	5.9	9.7	6.7	7.2
	Willingness-scenario	6.7	8.4	6.6	9.1	6.5	5.9	10.0	6.5	7.2

Factors influencing farmers' decisions

The decision of farmers to participate in campaign works and maintenance of SWC structures was influenced by their attributes and interactions with other actors. The following are four key attributes influencing farmers' decisions.

Wealth status: As shown in Table 4.2 and Table 4.3, under both the *default-scenario* and *willingness-scenario*, campaign and maintenance scores were higher for the middle-income farmers, particularly in Sara-Areda. In the subsequent discussions, the actors stated that participation in the program activities is lower for the poorest farmers since some farmers seasonally migrate to other localities in search of off-farm employment. Similarly, the actors stated that participation is lower for richest (better-off) farmers since they are usually busy with their non-farm activities in towns.

Distance from micro-watersheds: Distance negatively influenced the participation of farmers in the three *Kebeles* together and separately. The campaign score was lower for farmers that were relatively far away from the newly selected micro-watershed/s under both the *default-scenario* and *willingness-scenario* (Table 4.2). Similarly, the maintenance score was mostly lower for farmers that were far away from the micro-watersheds under both scenarios (Table 4.3).

Membership in micro-watershed associations: Farmers who were members of micro-watershed associations showed a higher level of participation in the campaign works and maintenance of the SWC structures under the *default-scenario* and *willingness-scenario* in both Ararso-Bero and Sara-Areda, as shown in Table 4.2 and Table 4.3. Observation of behavior of members of associations in the RPG shows that they frequently pushed the *Kebele* administrators to punish farmers with lower level of participation, because they assumed their annual income from SWC structures will reduce when participation of farmers is lower. In Qachachule-Guja, the absence of such associations could have contributed to the relatively lower campaign and maintenance scores.

Awareness of watershed degradation and future benefits of the CBWM program: During group discussions, farmers' awareness of the seriousness of watershed degradation and future benefits of the program was frequently cited by actors (e.g. extension workers, leaders of development teams, some farmers) as an important factor influencing their selection of new micro-watersheds and participation in campaign works, particularly in Qachachule-Guja. In addition, the actors stated that maintenance of SWC structures is higher for farmers with better awareness of the benefits of the structures in minimizing erosion problems.

In addition, in making decisions, farmers *interact with fellow farmers* and other local actors (*Kebele* administrators and extension workers). Interaction among farmers was observed during the selection of new micro-watersheds to be developed and campaign works. As shown in Figure 4.1, the Standard Error (SE) for campaign scores generally reduced as the game proceeded in all *Kebeles*. This means that the similarity of farmers' decisions increased overtime. It appears the decision of farmers converged to a moderate score as the game proceeded. Observations of farmers' behavior in the game sessions show that farmers copy the decisions of individuals they considered more knowledgeable. These individuals spontaneously emerged and were followed by other farmers in the game sessions. However, the SE rather increased over time for maintenance participation, particularly under the *willingness-scenario*, because some actors considered that maintenance of SWC structures should be carried out only after some years, but not immediately after they are constructed.

The interaction between *farmers and Kebele administrator* was unidirectional, where the latter used different measures ("aware", "reprimand", "punish") to motivate farmers to participate in campaign works and maintenance of SWC structures. In taking measures, observations during the game sessions showed that the *Kebele* administrator frequently consults the leader of the development team. In addition, in group discussions that follow, the actors aver that the quality and commitment of *Kebele* administrators are crucial to monitor the decisions of farmers regularly and take measures based on farmers' decisions.

As indicated in Figure 4.1, *Kebele* administrators take measures more during campaign works than maintenance of SWC structures. In addition, the measures have different degrees of influence on the decisions of farmers: “aware” (weak), “reprimand” (moderate), and “punish” (strong). This is best epitomized by the increase of campaign and maintenance scores when at least one of the farmers is reprimanded or punished at the previous time step (Figure 4.1). For instance, in Sara-Areda, reprimanding increased campaign score from 6.89 in 2018/19 to 7.78 in 2019/20, while punishment increased this score from 6.89 in 2019/20 to 7.78 in 2020/21 and maintenance score from 5 in 2019/20 to 8.89 in 2020/21. The *Kebele* administrators employ control instruments or more stringent measures (“reprimand” and “punish”) after trying to stimulate the farmers by using voluntary instruments or less stringent ones (“aware”) at the previous time step (Figure 4.1).

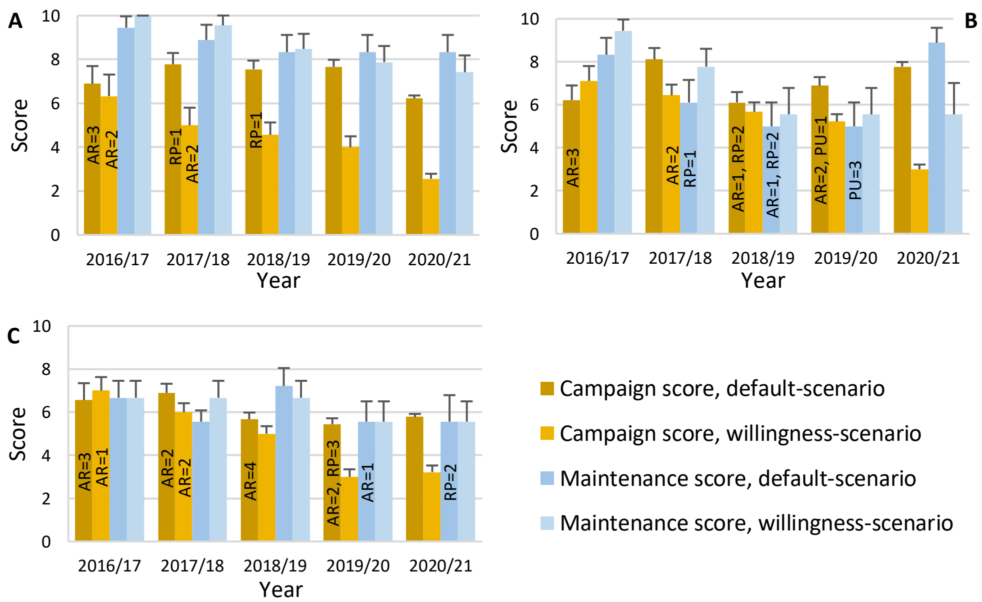

Figure 4.1 Patterns of change in farmers’ average campaign and maintenance scores in Ararso-Bero (A), Sara-Areda (B), and Qachachule-Guja (C). In the middle of some series are measures (AR = “aware”, RP = “reprimand”, and PU = “punish”) and number of farmers against measures was taken.

The interaction between the *farmers and extension workers* was also unidirectional, where the extension workers tried to persuade farmers to select micro-watersheds on upstream (steeper) areas before proceeding to the downstream (flatter) areas. During the game sessions, the extension workers used the average campaign and maintenance scores as well as the area of land covered with SWC structures to establish the content of their messages. In addition, during group discussions it became clear that the extension workers give technical support to the farmers during campaign works, though other actors belittled the involvement of extension workers in the maintenance of SWC structures. More importantly, the commitment of extension workers was regarded crucial to guide farmers during the selection of micro-watersheds and campaign works.

Game outcomes

Area of land covered with SWC structures (ha): The area of land covered with SWC structures was estimated and displayed at the end of each time step or year. As shown in Figure 4.2, the area of land covered with SWC structures declined over time in all *Kebeles*. The percentage change (**Δ**) between the initial (2015/16) and final years (2020/21) shows that the rate of change was lowest in Ararso-Bero and highest in Qachachule-Guja, indicating relatively better results in Ararso-Bero and lowest in Qachachule-Guja. In addition, the area of land covered with SWC structures is higher under the *default-scenario* than *willingness-scenario*, particularly in Ararso-Bero and Sara-Areda.

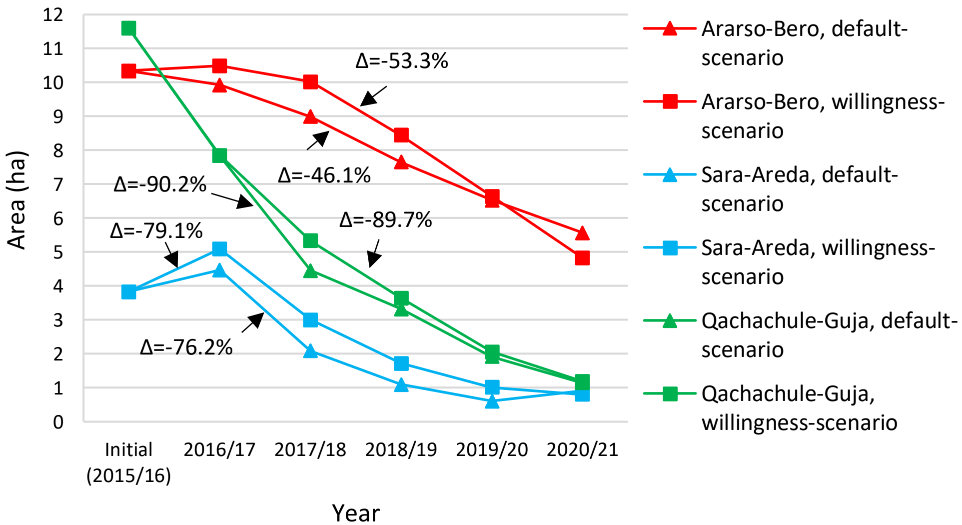

Figure 4.2 Patterns of change in area of land covered with SWC structures for Ararso-Bero, Sara-Areda, and Qachachule-Guja.

Income (birr): Total income was calculated for the farmers at the end of each time step or year based on their participation in campaign works and maintenance of SWC structures as well as income they obtained from SWC structures. At the end of the game sessions, the average income of the farmers is highest in Ararso-Bero and lowest in Qachachule-Guja (Figure 4.3). Unlike other *Kebeles,* average income steadily reduced as the game proceeded in Qachachule-Guja. Compared to the *default-scenario*, the average income of the farmers is highest under the *willingness-scenario* at the end of the game sessions in all the *Kebeles*.

In addition, the SE shows that income inequality among the farmers increased as the game proceeded, particularly in Ararso-Bero.

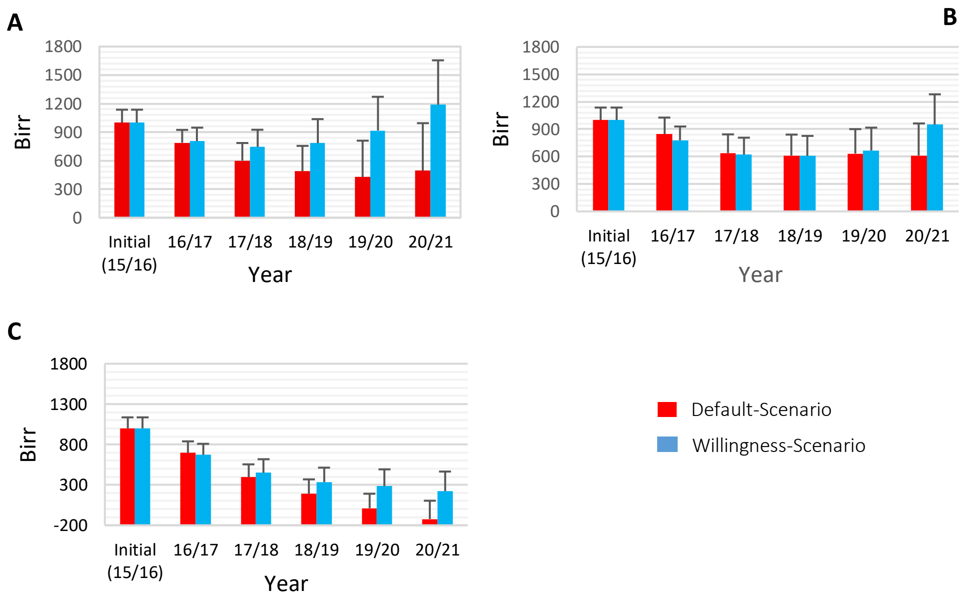

Figure 4.3 Patterns of change in average income of farmers in Ararso-Bero (A), Sara-Areda (B), and Qachachule-Guja (C) Kebeles.

4.3.3 Debriefing stage

Group discussions were held in each *Kebele* to identify collective alternative management strategies that will improve both area of land covered with SWC structures and income of the farmers (Figure 4.4). The actors identified several specific strategies that could be categorized into four key strategies. The first three are modifications on the existing CBWM program, while the last one requires change in the approach of the program.

The first strategy was motivating farmers through awareness raising trainings, incentives, and punishment. Awareness raising trainings and experience sharing to build the capacity of farmers was regarded as an important strategy by all actors in all the *Kebeles*. On the other hand, the use of incentives such as cash payment or food assistance was contentious among the actors. Some farmers argued incentives will ensure higher participation by curtailing the seasonal migration of poor farmers to other localities, particularly in Ararso-Bero. The extension workers explained the negative effect of cash payment and food-for-work to ensure the continuity of the program. In addition, the *Kebele* administrators and extension workers stated that cash payment or food-for-work are against government directives and beyond the capacity of local government actors to implement in their respective *Kebeles*. The actors finally agreed to exclude such incentives and agreed to give awards and recognitions to farmers with higher level of participation in campaign works and maintenance of SWC structures. Similarly, the actors discussed the importance of punishing disobedient farmers. Though there was a common understanding that punishing farmers is against the government directive, the actors decided to punish disobedient farmers by giving them more workload during campaign works and require cash payments.

The second strategy was establishing and strengthening the micro-watersheds associations for better maintenance of SWC structures on communal land. The actors discussed the need to establish micro-watershed associations in Qachachule-Guja. At first, both *Kebele* administrator and extension worker were not even willing to discuss the importance of establishing associations that will own and maintain SWC structures. They expressed their frustration since some farmers had fenced-off portions of the micro-watersheds illegally and obstructed the establishment of associations and maintenance of the SWC structures. Some farmers also indicated that establishing associations on the already developed micro-watersheds is simply a futile exercise since the boundary between communal land and private land is not properly delineated in some places. After thorough discussion, the actors agreed on the importance of delineating communal land in consultation with higher government authorities and establish associations of farmers in the vicinity of the micro-watersheds. The importance of including farmers living in the vicinity of the micro-watersheds and strengthening the existing associations was also discussed and agreed upon in Ararso-Bero and Sara-Areda, but the actors stated that strengthening associations requires the intervention of higher government authorities to give trainings as well as material and financial support.

The third strategy was capacity building of local government actors to improve their commitment during campaign works and maintenance of the SWC structures. The actors indicated that the commitment of *Kebele* administrators and extension workers is critical for the success of the program in all the *Kebeles*. For instance, in Qachachule-Guja, poor performance of previous *Kebele* administrators and their frequent change was mentioned as a major obstacle for a successful CBWM program. The actors emphasized government authorities should give trainings, follow-up and support the *Kebele* administrators and extension workers to improve their knowledge and commitment in the program.

The final strategy was to organize farmers into labor groups based on their willingness to collectively develop micro-watersheds on their own, without mass mobilization. This approach was suggested both in Sara-Areda and Qachachule-Guja. Some farmers suggested that they should be encouraged to organize themselves to collectively construct SWC structures on their farmlands as well as communal land in their neighborhoods. They also suggested that the role of *Kebele* administrators and extension workers could be limited to capacity building in the form of awareness raising, experience sharing, and technical support to motivate the farmers. Other farmers, particularly in Qachachule-Guja, indicated that farmers are less likely to participate in the campaign works without stringent mobilization by leaders of development teams and *Kebele* administrators. Discussions were also held on the side-effects of the approach, including overstretching work time of extension workers and integration at watershed level. The actors saw special advantage of the approach in ensuring micro-watershed management, but the *Kebele* administrators and extension workers indicated that they don't have a mandate to implement this strategy in their *Kebeles*.

Figure 4.4 Discussions among participants at the debriefing stage.

4.4 Discussions

4.4.1 Farmers' decision-making

This study gives insight into farmers' decision-making in the CBWM program. Results show that farmers preferred to collectively work on private farmlands in the downstream areas over communal lands located in upstream areas, because of the limited direct benefits of developing communal land (Assefa et al., 2018b) and physical accessibility of the farmland to the farmers (Assefa et al., 2018a). This implies farmers' lower awareness of the complexity of watershed degradation and its management, as well as their low motivation to invest in the future. It also shows that the participation of farmers in campaign works was higher under a *default-scenario* (where *Kebele* administrators use control instruments) than under a *willingness-scenario* (without control instruments). This indicates that farmers have a low intrinsic motivation to contribute labor for campaign works under the current condition, as also shown by Abi et al. (2019). However, the scenarios had more or less the same effect on farmers' maintenance decisions, because of the limited use of control instruments under the *default-scenario.* Overall, in line with Assefa et al. (2018b), the participation of farmers in campaign works and maintenance of SWC structures is higher in localities that are exposed to erosion problems.

As shown by Badal et al. (2006) and Assefa et al. (2018a), the participation of farmers in campaign works and maintenance of SWC structures was lower for poorer farmers who seasonally migrate to other localities in search of off-farm employment and the better-off farmers who are busy with their non-farm activities in towns. However, in agreement with other studies (e.g. Okumu and Muchapondwa, 2017), the decisions of farmers were negatively influenced by their distance from micro-watersheds. The influence of wealth status and distance suggests how location of farmers or proximity to micro-watersheds influence their participation in campaign works and maintenance of SWC structures. In addition, participation was higher for members of existing micro-watershed associations, because of the higher commitment of their members due to their better awareness of erosion problems, as well as the income they obtained from the micro-watersheds, as also shown by Dolisca et al. (2006). Similarly, in line with the findings of Kacho and Asfaw (2014), participation was higher for farmers with better awareness of watershed degradation and future benefits of the program. The importance of these two factors suggests that farmers' awareness and motivation are crucial in influencing their decisions. The decisions of farmers were also influenced by their interactions with other actors. As the game proceeded, consistent with the findings of Wesselow and Stoll-Kleemann (2017), the similarity of farmers' decisions increased during campaign works, because some farmers copy and/or receive advices from fellow farmers they considered more knowledgeable. Lastly, the decisions of farmers was influenced by the commitment of *Kebele* administrators who used different measures to encourage and enforce farmers to participate in the program. The measures have different degrees of influence on the decisions of farmers and the *Kebele* administrators employ control instruments after trying to stimulate farmers using voluntary instruments. However, in agreement with the finding of Leta et al. (2018), extension workers focused on giving awareness raising trainings to farmers, though the messages they communicate hardly reflect the need of farmers.

The results of farmers' decisions show that the *default-scenario* and *willingness-scenario* will not optimize both area of land covered with SWC structures and income of the farmers simultaneously. However, variation in income increases over time under both scenarios, implying that the existing income distribution mechanisms are likely to increase income variation and demotivate farmers to participate in the program (Assefa et al., 2018b).

4.4.2 Learning and collective decision-making

The study also provides mutual learning and collective decisions among actors at the three stages of the game. Learning began at the preparation stage when the actors discussed the existing lengths of SWC structures and area of land covered with SWC structures, how these outcomes were estimated, and reasons behind lower than expected outcomes of the program. Conversations among the actors enabled them to learn about limitations of the current accounting system of outcomes as well as maintenance practices. This suggests the importance of using more feedback and discussion sessions to enhance the quality of interaction and learning among local actors. Learning also occurred during the selection of new micro-watersheds and campaign works. Though initially farmers selected private farmlands in the downstream areas - ignoring communal land in upstream areas - after thorough discussions and negotiations the actors collectively decided on the feasible location of new micro-watersheds. During campaign works, farmers learned from decisions of fellow farmers, their own previous decisions, and actions (measures) of *Kebele* administrator. In this regard, the RPG was crucial to facilitate mutual understanding or actors learning of the perspectives of one another.

Learning and collective decisions mostly occurred at the debriefing stage of the game, where actors discussed and negotiated to identify four key strategies that enhance outcomes of the program. First, the actors collectively decided that awareness raising trainings, awards and punishment are crucial to motivate famers to participate in the program. However, awards and punishments are less likely to create intrinsic motivation (Deci and Ryan, 1985), and sense of ownership of SWC structures among the farmers, which are both crucial to enhance sustainable land management (Kessler, 2006). Second, the actors agreed on the importance of establishing and strengthening micro-watershed associations to enhance maintenance of SWC structures on communal land. They assessed the problem of poor conservation practices and suggested the importance of capacity building of the associations, where discussing this matter was very sensitive since some farmers fenced-off portions of the micro-watersheds on communal land illegally for private use. This shows the merit of the game to mediate conflicts and negotiate interests among farmers, as also shown by Souchère et al*.* (2010). Third, consistent with other similar studies (e.g. Assefa et al*.*, 2018a; Assefa et al*.*, 2018b), mutual understanding was created among the actors on the importance of capacity building of local government actors through trainings to develop their sense of ownership of the program. Finally, the actors collectively decided to adopt a new strategy that encourages farmers to organize into labor groups based on their willingness to collectively develop smaller micro-watersheds in their neighborhoods. Consistent with Souchère et al*.* (2010), the game empowered the actors to suggest and discuss initially unexpected management approaches.

4.5 Conclusions

The main objective of this study was to assess farmers' decision-making in the Campaign-Based Watershed Management (CBWM) program, as well as learning and collective decision-making among local actors in Boset District, Ethiopia. The study shows that farmers prefer to collectively work on private farmlands rather than on communal land, because of their limited awareness and motivation. It also shows that the participation of farmers in campaign works was higher under the *default-scenario* (with control instruments) than the *willingness-scenario* (without control instruments), indicating lower motivation of farmers to contribute labor without more stringent measures. During campaign works, farmers follow the decisions of a fellow farmer they considered more knowledgeable. However, farmers' maintenance decision was more or less the same under the *default-scenario* and *willingness-scenario*, because of limited use of more stringent measures under the *default-scenario*. Both farmers' level of participation in campaign works and maintenance decisions were influenced by location or proximity of farmers to micro-watersheds as well as their awareness and motivation. The decisions of farmers and factors influencing their decisions suggest the need *to motivate farmers through capacity building*; focusing on trainings particularly for model farmers and influential individuals, and introducing local alternative livelihood opportunities for the poorer farmers to minimize the effect of out-migration for employments.

Moreover, the commitment of *Kebele* administrators is crucial to take measures that encourage and enforce farmers to participate in the program. However, farmers tend to respond better to more stringent measures or control instruments ("reprimand", "punish") than the less stringent one ("aware"). The lower impact of less stringent instruments on farmers decisions indicates that the current awareness raising trainings are not adequate in enhancing intrinsic motivation and sense of ownership of the program. Thus, there is a need to focus on *capacity building of extension workers and Kebele administrators* so that they facilitate mutual learning, information exchange, and intrinsic motivation among the farmers.

The analysis of farmers decision-making shows that the two scenarios will not simultaneously enhance both area of land covered with Soil and Water Conservation (SWC) structures and their income. Even so, the existing benefit-sharing mechanisms tend to exacerbate income inequality. Nevertheless, the game enabled the actors to learn perspectives of one another on limitations of the program and make collective decisions on locations of new micro-watersheds to be developed and explore alternative management strategies. Hence, it is essential to employ *bottom-up planning not only to assess problems and promote locally sensitive management strategies*, but also to address the problem of farmers' distance from micro-watersheds by focusing on smaller watersheds. The effects that these strategies will have on the outcomes of the program could be more systematically analyzed by e.g. employing a more complex Agent-Based Model.

5. Using agent-based modelling to assess scenarios for enhanced soil and water conservation in the Boset District, Ethiopia

The sustainability of the ongoing Campaign-Based Watershed Management (CBWM) program in Ethiopia is questionable due to poor planning and implementation of the Soil and Water Conservation (SWC) structures. This study uses an empirically based Agent-Based Model to explore the effect of six scenarios (doing business as usual, motivating farmers, establishing and strengthening micro-watershed associations, introducing alternative livelihood opportunities for the poorer farmers, enhancing the commitment of local government actors, and integrating multiple interventions by jointly considering all previous alternative scenarios) on both area of land covered with and quality of SWC structures in three Kebeles (villages) of Boset District. The result of the scenario analysis reveals that integrating multiple interventions has the highest impact on enhancing SWC in all Kebeles, and within this scenario enhancing the commitment of local government actors through capacity building generates most effect and yet requires low investment. Motivating farmers, introducing alternative livelihood opportunities, and establishing and strengthening micro-watershed associations have limited, but differential influence on the outcomes of the program across the Kebeles. However, all aforementioned alternative scenarios have some added value compared to doing business as usual. Hence, in order to enhance the outcomes and sustainability of the ongoing CBWM program in the study area and other similar localities, it is crucial to give much more attention to enhancing the commitment of local government actors through capacity building. This empowers local government actors to (1) plan and more efficiently implement the program in consultation with other local actors, and (2) integrate locally sensitive need-based adaptation of the program.

Based on:

Assefa, S., Kessler, A. and Fleskens, L. 2020. Using agent-based modelling to assess scenarios for enhanced soil and water conservation in the Boset District, Ethiopia. Journal of Artificial Societies and Social Simulation (submitted)

5.1 Introduction

Agent-Based Modelling (ABM) has been used to investigate Socio-Ecological Systems (SES), focusing on testing theories (e.g. Jager et al., 2000; Parker and Meretsky, 2004), on conducting scenario-analysis to explore alternative strategies (e.g. Valbuena et al., 2008; Kaufmann et al., 2009; An, 2012), and on facilitating discussions, learning, and negotiations among actors (e.g. Campo et al., 2010; Smajgl, 2010; Naivinit et al., 2010; García-Barrios et al., 2011). Though not mutually exclusive, as ABM has become more widely used, there is a general tendency to develop more descriptive models that are underpinned by empirical data to conduct scenario analysis or explore alternative strategies (Matthews et al., 2007). This focus on descriptive models is mainly attributed to the increasing covet among policy makers for model-based evidences to make problems more tractable and back up their decisions (Clark and Holmes, 2010). A good example of a SES model that blurs the lines between the above mentioned purposes is shown in Pak and Brieva (2010), who used Role-Playing Games (RPGs) and interviews to construct an ABM that was used to facilitate discussions, learning, and negotiations among actors, and conduct scenario analysis.

The Campaign-Based Watershed Management (CBWM) program is a national initiative that has been implemented in Ethiopia since 2011/12 to conserve natural resources and improve rural livelihoods. The program epitomizes a complex SES as it has been carried out through mass mobilization of farmers, with the coordination of local administration and technical support of extension workers at the *Kebele* (village) levels. The main activities include constructing Soil and Water Conservation (SWC) structures (communal land, private farmland) and planting tree seedlings (communal land) for 30 to 40 days annually without any form of payment to the farmers (Wolka, 2014). The program has been acclaimed for ensuring the implementation of different SWC structures on a large area at low cost in a short period of time (Haregeweyn, et al., 2015; Teshome et al., 2016b). The sustainability of the program activities however is often questioned concerning: its top-down planning approach (Snyder et al., 2014; Assefa et al., 2018a); low awareness and motivation of farmers to participate in the program (Abi et al., 2019; Assefa et al., 2018a); poor commitment of local government actors due to limited knowledge and skills, poor logistics, and inadequate budget (Assefa et al., 2018a; Assefa et al., 2020); focus on construction of SWC structures giving less attention to livelihoods (Wolka, 2014; Abi et al., 2019); and little attention to the maintenance of the SWC structures (Snyder et al., 2014; Assefa et al., 2018a). These aspects point to different weaknesses of the CBWM program that have not yet been analysed systematically in the context of a complex SES. Hence, implementing ABM in the CBWM program will extend our understanding of the system by virtually experimenting with different management options, and suggesting a management strategy that ensures more sustainable impact.

This requires developing an ABM model from scratch using empirical data collected through multiple methods. Models that are constructed using in-depth data from the field can successfully be used for the purposes of social learning and scenario analysis (Pak and Brieva, 2010; Fleskens et al., 2014). The main purpose of this paper is to briefly present a description of the conceptual model and an analysis of model results to explore alternative watershed management strategies, by comparing outcomes generated by the different scenarios in and across three *Kebeles* (villages) in Boset District. The main interest is to show broader patterns of change in coverage with and variations in quality of SWC structures under different scenarios.

5.2 Materials and methods

5.2.1 Study area

The ABM was developed and applied for a study area that covers three adjacent *Kebeles* of Boset District: Ararso-Bero, Sara-Areda, and Qachachule-Guja. In terms of drainage system, the selected *Kebeles* fall in the Awash River Basin. In terms of quantity and quality as well as farmers' ownership of activities implemented in the CBWM program, the performance of Ararso-Bero is the best in the District while Sara-Areda and Qachachule-Guja are moderate and weak respectively (BDAO, 2015). In the past five years, five micro-watersheds were developed in Sara-Areda and Qachachule-Guja, while four micro-watersheds were developed in Ararso-Bero (Assefa et al., 2018a). The main activities of the program are selecting new micro-watersheds, constructing SWC structures through campaign works, and maintenance of the structures.

5.2.2 Description of the model

The development of the model began with the assessment of attributes, decision-making behavior, and interactions among actors using household surveys and interviews (Assefa et al., 2018a). The outcomes of the program were explored using Google Earth Engine, a household survey, and interviews to calibrate the most important parameters (Assefa et al., 2018b). The first conceptual model was prepared using Unified Modelling Language (UML). RPGs were then used to further explore the behavior of actors and their interactions, and explore scenarios to be tested in the model (Assefa et al., 2020). Following Balke and Gilbert (2013) and Johnson et al. (2014), the model is designed by deriving probabilities of behaviors from empirical data and then attaching these to agents, and using more qualitative data to identify the behavior of actors and parameter values. The description of the conceptual model was then elaborated using the Overview, Design concepts, and Details (ODD) protocol (Grimm et al., 2010) (*see* appendix 2). This was followed by the development of a computer model in NetLogo v6.2 (Wilensky, 1999). The model code can be found at https://www.comses.net/codebases/54aef9da-1255-43c3-a32c-4b1a45f14366/releases/1.0.0/.

The model simulates the CBWM program in three *Kebeles* of Boset District to explore conditions that enhance coverage with and quality of SWC structures. It has 36 system parameters with their default values and ranges (*see* appendix 2.1). This model includes three agents (farmers, *Kebele* administrator, extension workers) and the physical environment that interact with each other. The physical environment is represented by fields, and each field is equal to 0.25 ha. The fields have attributes of slope, land use (farmland vs communal land), whether it is inside a selected/developed micro-watershed or not, whether it has SWC structures or not, and the quality of SWC structures. The topography of the landscape is diffused from highest slope to lowest. Land use is assigned to fields based on slope, where all fields with slope > 30% is considered communal land (Gebreselassie et al., 2015). The initial number of micro-watersheds and area of land with SWC structures was set based on empirical data collected from the *Kebeles* (Assefa et al., 2018b). The initial quality of SWC structures in 2015/16 is an average of 100 runs set in the calibration process, i.e. the model was initiated in 2011/12 and average quality in 2015/16 was adopted as initial value for scenario analysis. The farmers are created and randomly distributed to farmland. All farmers own farmland in their vicinity. Some are members of micro-watershed associations. Table 5.1 shows static and dynamic state variables of the farmers. The values of most state variables were assigned to farmers randomly based on normal distributions with mean and standard deviations collected from the *Kebeles*. Income was set by initiating the model in 2011/12 and average income in 2015/16 was used as initial value for scenario analysis.

The *Kebele* administrator has two static state variables: *position* (coordinates) and *commitment-Kebele-administrator* (showing the commitment of *Kebele* administrator), ranging between 0 and 10. The extension workers have two similar static state variables: *position* (coordinates) and *commitment-extension-workers* (showing the commitment of the extension worker), ranging between 0 and 10. *Kebele* administrator and extension workers were placed around the center of the physical environment, and the values of their state variables (i.e. commitment) were set based on qualitative data and calibration of the model.

***Table 5.1** State variables of farmers.*

State variables	Values	Descriptions
position (static)	Coordinates	Randomly distributed at initialization to fields on farmland.
own-farmland (static)	Patch-Id	Each farmer owns the fields or farmland in their vicinity; set based on average farm size of the three *Kebeles.*
education (static)	0-10	Shows the class farmers completed (0 = Illiterate, 10 = 10 and above); randomly distributed at initialization.
extent-off-farm-participation (static)	0-10	Shows the extent to which the farmer participates in off-farm activities; randomly distributed at initialization.
degree-participation-local-organizations (static)	0-10	The extent to which the farmer participates in different local organizations; randomly distributed at initialization.
perceived-performance-*Kebele*-administrator (static)	0-10	Shows farmer's perception of the commitment of *Kebele* administrator; randomly distributed at initialization.
income (dynamic)	>= 0	Initial wealth (stock) of the farmer (birr); randomly distributed at initialization.
social capital (dynamic)	0-10	Shows the position or status of the farmer in the *Kebele*; randomly distributed at initialization.
perception-watershed (dynamic)	0-10	Shows farmer's perception of the problem of watershed degradation and future benefits of the program; randomly distributed at initialization.
membership-watershed-association (dynamic)	True / False	Shows whether this farmer is a member of micro-watershed association or not.
commitment-member-micro-watersheds (dynamic)	0-10	Shows the commitment of members of micro-watershed associations; randomly distributed at initialization.
measures (dynamic)	praise, no measure, aware, reprimand, punish	Shows the measure taken against this farmer by *Kebele* administrator. "No measure" at initialization.

The model has three key processes: (1) selection of new micro-watersheds to be developed, (2) construction of SWC structures through campaign works, and (3) maintenance decisions, where agents interact based on their roles and responsibilities. Every time step or year, the agents meet to select a new micro-watershed. The movement of farmers to the meeting center and their selection of technically viable (higher slope) fields depends on their *perception-watershed*. The movement of extension workers and *Kebele* administrator to the meeting center depends on their commitment. The main objective of extension workers is to improve the farmers' *perception-watershed* of the program so that they first select fields upstream (with steeper slopes). But the influence of extension workers depends on their commitment. The *Kebele* administrator also aims to ensure the selection of fields upstream, before proceeding to the lower areas. Depending on his/her commitment, he/she has the authority to enforce the selection of particular fields.

During campaign works, the agents are expected to move to the newly selected micro-watershed to exert their responsibilities. Farmers randomly occupy fields in the selected micro-watershed to build SWC structures. They make decisions to participate in campaign works either due to their own attributes or by copying the decision of their neighbor with highest *perception-watershed* of the program. The extension workers randomly move in the selected micro-watershed to ensure the quality of SWC structures. At this stage, the *Kebele* administrator has dual roles: (1) take measures based on farmers' level of participation, and (2) establish a new association when the micro-watershed is on communal land.

Based on their attributes, farmers could either decide to "maintain", "ignore" or "demolish" SWC structures. Farmers whose maintenance decision is "maintain" or "demolish" randomly move to the micro-watersheds to repair and remove the structures respectively. A farmer whose maintenance decision is "ignore" doesn't move. Ignored SWC structures decay overtime. At this stage, the extension workers and *Kebele* administrator randomly move across all micro-watersheds to ensure maintenance quality of SWC structures and to take measures based on farmers' decisions respectively. The movement of both extension workers and *Kebele* administrators depends on their commitment.

Each time step in the simulation represents one year, which updates the dynamic attributes of farmers, area of land covered with SWC structures, and quality of SWC structures. The simulation runs for 25 years, but this can be adjusted in the interface of the model. The random seed is used during sensitivity analysis, calibration of parameters, and scenario analysis.

5.2.3 Scenario definition

The scenarios are essentially modifications on the ongoing CBWM program and constitute motivating farmers, establishing and strengthening micro-watershed associations, introducing alternative livelihood opportunities for the poorer farmers, enhancing the commitment of local government actors, and integrating the above interventions. All the scenarios were obtained from previous analysis on the program (Assefa et al., 2018a; Assefa et al., 2020). They are framed as "what-if" situations with different initializations, rather than as pathways of how to evolve from the current program. They are described as follows using illustrative terms.

Default-scenario: Business as usual

This scenario is simulated to establish a baseline and compare this with other scenarios. It shows patterns of change in outcomes of the program in the current condition or without any modification. In this scenario, all variables of farmers, extension workers, and the *Kebele* administrator are fixed and all model parameters are set to the values for which the model is validated.

Motivation-scenario: Enhance farmers' awareness and motivation through capacity building
In the CBWM program, the awareness and motivation of farmers influence their level of participation in all *Kebeles* and stages of the program (Assefa et al., 2018a; Assefa et al., 2020). This is best epitomized by farmers' perception of watershed degradation and future benefits of the program and literacy education in the study *Kebeles*. In this scenario, farmers' *perception-watershed* is set to the maximum value of 10 and the level of *education* was doubled (Table 5.1). In addition, though there was a common understanding that punishing non-participating farmers is against the government directive, local government actors punish disobedient farmers (Assefa et al., 2018a). Considering that this approach is less likely to ensure genuine participation and intrinsic motivation, punishment is excluded from the model in this scenario.

Association-scenario: establishing and strengthening micro-watershed associations
In the post-implementation stage of the CBWM program, micro-watersheds on communal land are handed over to associations, which are supposed to maintain, protect, and use the micro-watersheds. In reality, in Qachachule-Guja, not a single micro-watershed was handed over to associations and there has not been any maintenance of the micro-watersheds. In other *Kebeles*, the associations rarely undertake maintenance due to their poor institutional, financial and technical capacities (Assefa et al., 2018a). To show the establishment of new micro-watershed associations *n-new members* is set at 10 (default number of members every year). In order to denote strengthening micro-watersheds associations, *commitment-of-members* is set at the maximum value of 10 at initialization. In the model, *commitment-of-members* is updated based on income from micro-watersheds (financial capacities), social capital among members (institutional capacities), and perception-watershed (technical capacities).

Livelihood-scenario: introducing alternative livelihood opportunities
Out-migration for off-farm employment limits the availability of farmers to participate in the CBWM program (Assefa et al., 2018a; Assefa et al., 2020). Hence, it is important to integrate and diversify program activities for better local livelihood opportunities and minimize seasonal migration of farmers to other localities. This will enhance the willingness of farmers to genuinely participate in the program. In the *livelihood-scenario*, the poorer segment of the farmers (total wealth <= 500 birr) receive additional income (500 birr) every year. Income minimizes farmers' level of participation in off-farm activities in other localities and enhances their participation in the program.

Commitment-scenario: enhancing the commitment of local government actors through capacity building

Capacity building of local government actors is essential to empower and motivate local leaders to develop their sense of ownership of the program so that they can motivate farmers to engage in the program and ensure quality constructions of SWC structures (Asssefa et al., 2018a; Asssefa et al., 2020). In this scenario, *number-of-extension-workers* is set to three (standard number) and both the *commitment-of-extension-workers* and *commitment-of-kebele-administrator* are set at the maximum value of 10.

All-scenario: integration of multiple interventions

This scenario involves integrating *motivation-scenario*, *association-scenario*, *livelihood-scenario*, and *commitment-scenario* to assess the joint effect of these interventions.

5.2.4 Observed outcomes

The effect of scenarios on the performance of the CBWM program was evaluated in the three *Kebeles* using two model outcomes:

(1) *Area of land covered with SWC structures:* In this model, this outcome is reported in hectare. Patches with SWC structures quality score of greater than or equal to one (i.e. >= 1) are considered to have SWC structures.

(2) *Quality of SWC structures*: Average score of the quality of SWC structures on fields that SWC structures have been constructed on. The score ranges between 0 and 10 (0 = no SWC structures, 10 = highest quality).

5.2.5 Simulation procedure: verification, sensitivity analysis, calibration and validation

Different strategies were employed to make the model "bug free" or ensure that it does what it is intended to do, including (1) employing multiple methods in the collection of empirical data that is used to setup the model, (2) using a number of intermediate outcomes and diagnostics, (3) testing the model with parameter values that are at the extremes of what is possible and ensure that the outcomes are reasonable, and (4) following both agents and patches during simulations to check that their behavior is in line with expectations.

The simulation of the model starts in the year 2011/12 and ends in 2040/41. The period between 2011/12 and 2015/16 was used to calibrate the model using the data obtained through Google Earth Engine. One-at-a-time sensitivity analysis was used to get insight in how changes in parameter values influence model outcome by varying values of one parameter, while keeping values of others parameters at the default settings. Each configuration of input parameters was run 100 times to calculate a Sensitivity Score (SS) of each parameter. Parameters with a relatively high value of SS indicate processes that are important in the model, while those with low value of SS indicate relatively unimportant processes that could be left out of further sensitivity analysis (Railsback and Grimm, 2012). SS was calculated for the three *Kebeles* using both *area of land covered with SWC structures* and *quality of SWC structures* (Table 5.2).

Table 5.2 *Sensitivity score for the most important and most uncertain parameters.*

No	Parameters	Ararso-Bero		Sara-Areda		Qachachule-Guja	
		Area with SWC	Quality of SWC	Area with SWC	Quality of SWC	Area with SWC	Quality of SWC
1	perception-watershed-selection-threshold*	-0.014	0.042	0.002	-0.002	-0.934	-1.000
2	*kebele*-administrators-move-campaign-threshold*	-0.590	-0.753	-0.642	-0.861	-0.068	-0.020
3	w-perceived-performance-*kebele*-administrator-maintenance**	1.361	1.865	1.182	1.650	0.113	0.249
4	w-off-farm-participation-maintenance**	1.466	2.193	1.411	1.941	0.399	0.776
5	w-perception-watershed-maintenance**	0.946	1.390	0.835	1.206	0.063	0.196
6	maintenance-threshold*	-3.151	-4.789	-2.910	-4.067	-0.594	-1.277

* Little knowledge about parameter values (no empirical data was available)

** Little knowledge about parameter values (inconsistency of empirical data obtained through interviews, household survey, and RPG)

The most important (as determined by SS) and most uncertain (absence of reliable empirical data) parameters were calibrated to reduce their uncertainty. This involves finding good values for a few especially important parameters by assessing what parameter values cause the model to reproduce patterns observed in the real system. In this study, calibration was conducted by comparing observed data on area of land covered with SWC structures between 2011/12 and 2015/16 (Assefa et al., 2018b) with data predicted by the model. Root Mean Square Error (MSE) shows that the model adequately predicted the patterns of area of land covered with SWC structures in the *Kebeles*, particularly in Ararso-Bero (Figure 5.1).

The calibration of the model was followed by validation, which was conducted to determine if the model is an adequate representation of the real system. The conceptual model developed through a household survey, key informant interviews, and individual case studies was validated by conducting RPGs to refine behavior rules underpinning decisions of agents within the ABM. The scenarios are triggered in the year 2016/17, since empirical data used to setup the model was mostly collected in the year 2015/16.

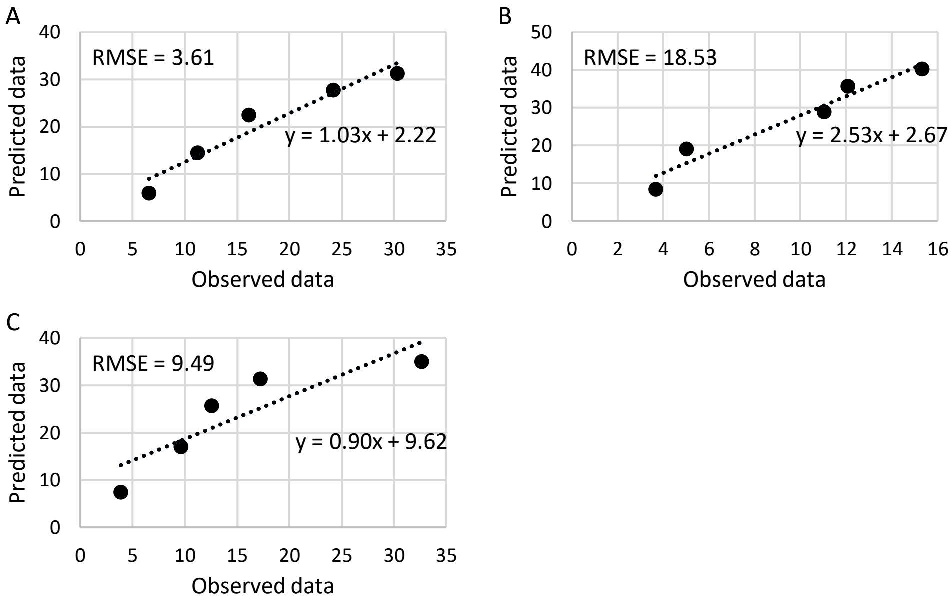

Figure 5.1 Comparison of observed and predicted data in Ararso-Bero (A), Sara-Areda (B), and Qachachule-Guja (C). Both observed and predicted data increased from 2011/12 to 2015/16 for the three Kebeles.

5.3 Results and discussion

This section presents the effect that the six scenarios or management options have on the patterns of change of area of land covered and quality of SWC structures over 25 time steps or years. It also presents the degree of influence of the scenarios on these outcomes in order of their importance. All the results represent an average of 100 simulation runs.

5.3.1 Patterns of change in model outcomes

The result of the scenario analysis shows that the area of land covered with SWC structures increases over time for all scenarios in all *Kebeles*, while the quality of SWC structures decreases - except for all-scenario in Ararso-Bero and Qachachule-Guja (Figure 5.2). This could be attributed to the construction of more SWC structures through annual campaign works, and yet limited maintenance and ownership of the structures. In addition, as shown in Figure 5.2, there is a steeper decline in quality of SWC structures at the beginning of the simulation (until 2020/21), because farmers mostly work on communal land during this period, where maintenance of SWC structures is lower than on private farmland. Consistent with other studies (Snyder et al., 2014), maintenance of SWC structures on communal land is the main challenge and this suggests from the outset the need to integrate multiple interventions (all-scenario), focusing on enhancing the commitment of local government actors through capacity building (commitment-scenario) for better results.

Another notable result is that both the *all-scenario* and the *commitment-scenario* increase area of land covered with SWC structures linearly from the initial year and keep the quality of SWC structures around average in all *Kebeles* (Figure 5.2). These scenarios result in higher outcomes compared to the *default-scenario* starting from the beginning of the simulation (for quality of SWC structures) and around 2030/31 during the mid of the simulation (for area of land covered). The difference between outcomes from these scenarios and those of the *default-scenario* also increases over time. This suggests that the scenarios are important both in the short-term and long-term and their influence increases over time. It appears that enhancing the commitment of local government actors through capacity building increases achieving the outcomes faster, because the actors will effectively take their responsibilities in the CBWM program using different strategies, including control instruments.

The patterns of change in area of land covered and quality of SWC structures under the *motivation-scenario*, *livelihood-scenario*, and *association-scenario* are similar to the one observed during the *default-scenario* in Sara-Areda and Qachachule-Guja. In Ararso-Bero, the area of land covered with SWC structures increases over that of the *default-scenario* after the mid of the simulation (2030/31). The quality of SWC structures, however, is consistently higher than that of the *default-scenario* from the beginning to the end of the simulation in this *Kebele*. In general, these scenarios affect the outcomes of the program in the long-term, because it takes time to increase the required awareness and perceptions of farmers for action (Valente and Myers, 2010). Similarly, as shown by Wondimagegnhu and Zeleke (2007), introducing livelihood opportunities for the poorer farmers considerably minimizes out-migration for off-farm employment when farmers couple this with income they obtain from SWC structures in the long-term.

In summary, integrating multiple interventions and enhancing the commitment of local government actors are crucial to enhance maintenance of SWC structures, particularly on communal land and generate better outcomes both in the short-term and long-term; while investing in farmers, i.e. motivating farmers, introducing alternative livelihood opportunities for the poorer farmers, and establishing and strengthening micro-watershed associations result in better outcomes only in the long-term.

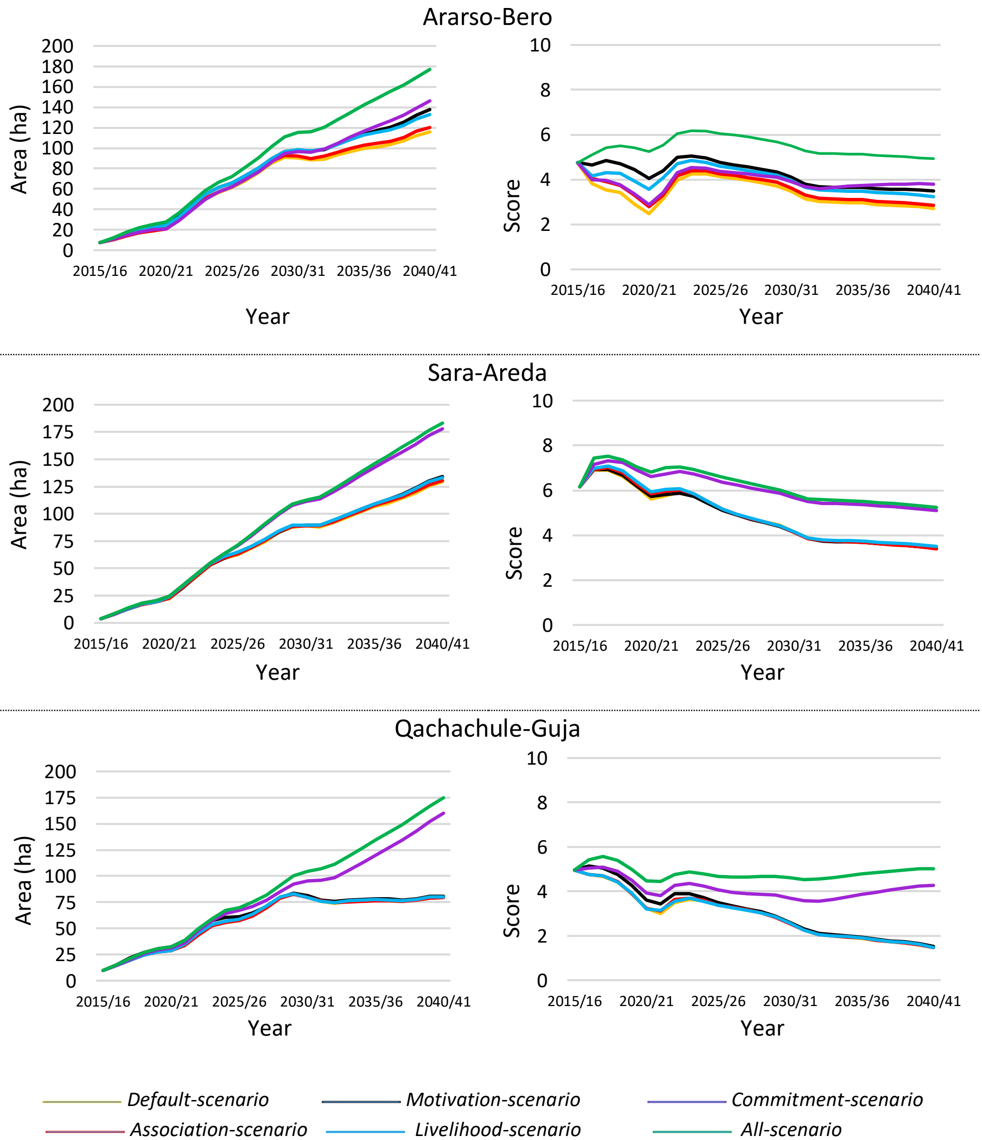

Figure 5.2 Pattern of change in area of land covered and quality of SWC structures in Ararso-Bero, Sara-Areda, and Qachachule-Guja.

5.3.2 Effect of scenarios on model outcomes

All-scenario

Integrating multiple interventions creates the highest impact in enhancing both area of land covered with and quality of SWC structures in all *Kebeles*. On average, under this scenario, the area of land covered with SWC structures increases by 171.3 ha, while the quality of the structures decreases by 3.3% over 25 years (Table 5.3). It appears that motivating farmers, establishing and strengthening micro-watershed associations, introducing alternative livelihood opportunities for the poor, and enhancing the commitment of local government actors jointly are crucial to enhance outcomes of the program. This confirms the widely held views that watershed management initiatives should not only focus on conservation of natural resources, but also on building the capacity of local institutions and livelihood of the people concerned (Kerr, 2002; Shiferaw et al., 2009). Such interventions are more likely to ensure collective action for watershed management, spreading of the SWC structures to other localities and sense of ownership of the structures among local actors (Desta et al., 2005), and even spillover effects to other similar sectors (Abi et al., 2019). The main challenge, however, is that implementing these strategies requires considerable resources and collaboration among various actors (higher government authorities, sectoral offices), which is lacking in the current CBWM program in the country (Abi, 2019).

Table 5.3 *Change in area of land covered (ha) and quality (%) of SWC structures between the initial (2015/16) and final (2040/41) year.*

Scenarios	Ararso-Bero		Sara-Areda		Qachachule-Guja		Mean	
	Area of land	Quality of SWC	Area of land	Quality of SWC	Area of land	Quality of SWC	Area of land	Quality of SWC
Default-scenario	108.3	-42.8	125.7	-44.7	70.6	-70.2	101.5	-52.6
Association-scenario	112.7	-39.9	126.7	-45.0	69.9	-70.5	103.1	-51.8
Livelihood-scenario	125.3	-31.8	129.4	-43.3	70.1	-70.4	108.3	-48.5
Motivation-scenario	130.2	-26.4	130.4	-44.8	70.7	-69.4	110.4	-46.9
Commitment-scenario	138.7	-20.1	174.1	-17.3	150.3	-13.6	154.4	-17.0
All-scenario	169.5	3.6	179.4	-15.1	165.5	1.5	171.3	-3.3

Commitment-scenario

The *commitment-scenario* involves enhancing the commitment of local government actors through capacity building so that they effectively take-up their roles and responsibilities in the CBWM program. As shown in Table 5.3, the *commitment-scenario* is the second best option to enhance both area of land covered and quality of SWC structures in all *Kebeles*. On average, under this scenario, the area of land covered with SWC structures increases by 154.4 ha, while the quality of structures decreases by 17.0% over 25 years (Table 5.3). This confirms the significance of local governance in the collective watershed management initiatives (Araral, 2009; Ratner et al., 2013; Nagendra and Ostrom, 2014) and in the CBWM program in particular (Wolka, 2014). Similar to the *all-scenario*, the *commitment-scenario* has important spillover effects since the local government actors are also responsible for other extension services. This scenario is the most efficient strategy of all since it requires limited investments compared to *all-scenario* that involves multiple activities and yet produces reasonable outcomes. Compared to the *all-scenario*, the contribution of the *commitment-scenario* is relatively lower in Ararso-Bero (Table 5.3), which indicates the need to introduce additional interventions for better outcomes in this *Kebele*.

Motivation-scenario

As shown in Table 5.3, motivating farmers through voluntary instruments is the third important scenario to enhance outcomes of the program. On average, the *motivation-scenario* increases area of land covered with SWC structures by 110.4 ha, while it decreases the quality of the structures by 48.9% over 25 years. Among the studied *Kebeles*, the *motivation-scenario* has more added value compared to the *default-scenario* and generates better outcomes over the 25 years in Ararso-Bero (Table 5.3). The importance of this scenario could be related to the strong performance of *Kebele* administrators and extension workers, lower farmers' perception of watershed degradation and future benefits of the program, and lower use of control instruments in this *Kebele* (Assefa et al., 2020). In Sara-Areda, though change in outcomes over 25 years is more or less the same to Ararso-Bero (Table 5.3), this scenario has less added value compared to the *default-scenario*, because of a relatively better initial condition of this *Kebele* in terms of perception of watershed degradation and future benefits of the program (Assefa et al., 2018a). However, the lower effect of the *motivation-scenario* in Qachachule-Guja is related to poorer capacity of extension workers and *Kebele* administrators to exert their responsibilities in the CBWM program.

In general, the effect of the *motivation-scenario* is relatively higher in a context where the performance of local government actors is relatively strong, and initial farmers' awareness and motivation is lower. This scenario has less added value in localities that have been frequently employing control instruments. Though motivating farmers is crucial to create intrinsic motivation and sense of ownership (Kessler, 2006; Abi et al., 2019), their contribution will be compromised if the performance of local government actors is either weak or if they use control instruments. Thus, voluntary instruments will have more added value if wisely employed together with control instruments that will be developed locally with the participation of farmers.

Livelihood-scenario

Introducing alternative livelihood opportunities for poorer farmers is the fourth important scenario to enhance outcomes of the program. On average, under this scenario, area of land covered with SWC structures increases by 108.3 ha, while the quality of SWC structures decreases by 48.5% over the 25 years. Though this scenario results in better outcomes over the 25 years in Sara-Areda, it has less added value compared to the *default-scenario* (Table 5.3). In Ararso-Bero however, this scenario has more added value compared to the *default-scenario* and produces reasonable outcomes, because farmers seasonally migrate to other localities for off-farm employment due to their lower agricultural outputs and smaller land size (Assefa et al*.*, 2018a).

Conversely, the effect of *livelihood-scenario* is the lowest in Qachachule-Guja as some farmers are not eligible for alternative livelihood opportunities because of their relatively higher income and lowest out-migration for off-farm employment. In this regard, the *livelihood-scenario* is a viable strategy in a relatively poorer communities where farmers temporarily migrate to other localities in search of means of livelihood. Unlike approaches focusing on restoring natural resources for better rural livelihoods (Kerr, 2002; Darghouth, et al*.*, 2008; Shiferaw et al*.*, 2009), this strategy emphasizes the importance of local livelihood diversification for poorer seasonal migrants so that they are enabled to contribute to natural resource conservation.

Association-scenario
Establishing and strengthening micro-watershed associations is the fifth important scenario in enhancing the outcomes of the program. On average, under this scenario, area of land covered with SWC structures increases by 103.3 ha, while the quality of SWC structures decreases by 51.8% over the 25 years. It appears that enhancing financial, institutional, and technical capacities of the associations has marginal impact on the outcomes of the program. Particularly in Qachachule-Guja, the effect of this scenario is lower than that of *default-scenario* since the commitment of local government actors is weaker and members of the newly established associations are less likely to take their responsibilities without solid support and follow-up from these actors. The *association-scenario* has more added value compared to the *default-scenario* in Ararso-Bero, where performance of local government actors is strong, and initial awareness and motivation of farmers is lower than other *Kebeles*.

From the lower contribution of the *association-scenario* one could question the added value of establishing associations to ensure maintenance of SWC structures on communal land and to serve as benefit sharing mechanism. One possible reason for the lower contribution of this scenario are the limitations of the already established associations, such as including very few farmers, limited economic benefits incurred from micro-watersheds, and the fact that skills and experiences of members hardly spread to non-members. Limitations while establishing new associations also play a role, especially failure to include real target groups, exclusion of non-members from decision-making and any short-term economic benefits, and consequent violent conflict between members and non-members in some localities (Assefa et al*.*, 2018a). However, the sustainability of SWC structures on communal land depends on the cooperation of non-members. In this regard, non-members’ sense of ownership of the micro-watersheds on communal land is crucial. This suggests the importance of establishing associations through transparent and participatory processes or devise other more viable or locally sensitive strategies for the maintenance of SWC structures on the treated communal micro-watersheds.

Default-scenario

This scenario simulates the effect of continuing with the current conditions. As shown in Table 5.3, the *default-scenario* results in the lowest outcomes compared to all alternative scenarios. Across the *Kebeles*, the area of land covered with SWC structures increases only by 70.6 ha in Qachachule-Guja over 25 years, compared to an increase of 125.7 ha in Sara-Areda and 108.3 ha in Ararso-Bero. Though the quality of SWC structures gradually declines from the beginning to the end of simulation in all *Kebeles*, the rate of decline is highest in Qachachule-Guja (70.2%), compared to Ararso-Bero (42.8%) and Sara-Areda (44.7%). Hence, continuing with the current conditions generates the lowest outcomes in Qachachule-Guja, where performance of *Kebele* administrators and extension workers is poorer and maintenance of SWC structures on communal land is lacking (Assefa et al., 2018a, Assefa et al., 2018b).

Overall, the result of scenario analysis shows that the default-scenario or doing business as usual results in the lowest outcomes compared to other alternative scenarios, particularly where performance of local government actors is poorer and mechanisms for maintenance of SWC structures on communal land is lacking. More importantly, the gradual decline in quality of SWC structures under this scenario suggests that the structures get less effective in controlling water erosion and will be completely destroyed in the long-term. In this regard, continuing with the current conditions is less likely to ensure sustainability of SWC structures. This confirms results from studies that question the sustainability of the ongoing CBWM program in the country (e.g. Snyder et al., 2014; Assefa et al., 2018a; Assefa et al., 2020), without adapting or addressing key limitations of the program (Abi et al., 2019).

Summary of added value of alternative scenarios compared to default-scenario

Percentage change between the alternative scenarios and the default-scenario was used to determine the added value or relative importance of implementing alternative scenarios. Overall, all alternative scenarios have some added value compared to the *default-scenario* or doing business as usual (Figure 5.3). Among the tested scenarios, *all-scenario* or integrating multiple interventions has highest added value in all *Kebeles* together and separately. On average, this scenario increases area of land covered with and quality of SWC structures by 68.77% and 93.73% respectively over *default-scenario*. Compared to the default-scenario, the effect of the *all-scenario* is particularly highest in Qachachule-Guja, where it increases the area of land covered and quality of SWC structures by 134.42% and 102.14% respectively. The second important scenario is the commitment-scenario, which on average increases area of land and quality of SWC structures by 52% and 68% respectively over default-scenario. This scenario is the second important in all the studied *Kebeles* compared to the *default-scenario*. The other three alternative scenarios, i.e. the *motivation-scenario*, *livelihood-scenario*, and the *association-scenario* are only important in Ararso-Bero (Figure 5.3), where performance of local government actors is strong, initial awareness and motivation of farmers is lower, and where farmers seasonally migrate to other localities for off-farm employment. In other *Kebeles*, these scenarios have less added value.

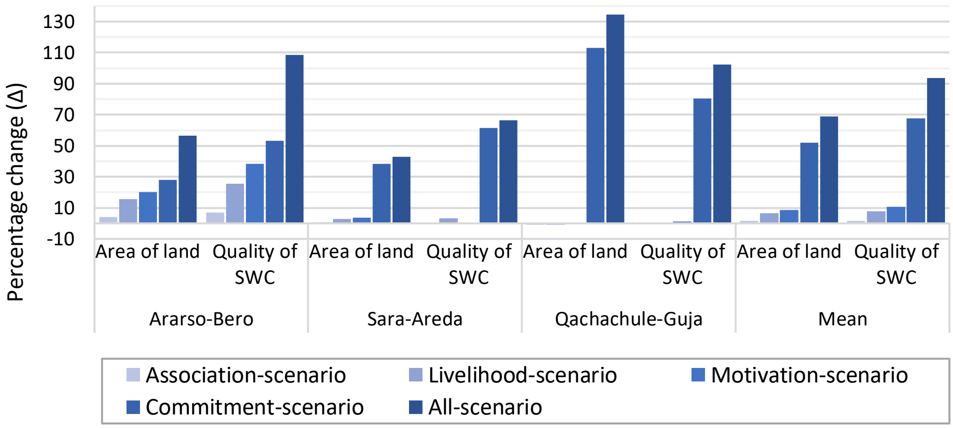

Figure 5.3 Percentage change in outcomes of the model due to alternative scenarios over default-scenario.

5.4 Conclusions

The main objective of this study was to explore conditions that enhance the outcomes of the Campaign-Based Watershed Management (CBWM) program by using an empirically based Agent-Based Model in Boset District, Ethiopia. The model analyzed the extent to which six scenarios enhance the area of land covered with and quality of Soil and Water Conservation (SWC) structures. The results of the scenario analysis reveal that integrating multiple interventions, including enhancing the commitment of local government actors, motivating farmers, introducing alternative livelihood opportunities for the poor, and establishing and strengthening micro-watershed associations result in highest outcomes. However, this strategy requires huge resources and collaboration among various actors. A more efficient strategy is to focus on capacity building of local government actors, since this produces reasonable outcomes and yet requires lower investment compared to integrating multiple interventions. Similar to integrating multiple interventions, this strategy has spillover effects, empowers local government actors, enhances maintenance of SWC structures particularly on communal land, and generates better outcomes both in the short-term and long-term. However, motivating farmers, and establishing and strengthening micro-watershed associations in isolation are important where performance of local government actors is strong, and initial awareness and motivation of farmers is lower. Introducing alternative livelihood opportunities is crucial where poorer farmers seasonally migrate to other localities for off-farm employment. Even so, these strategies result in better outcomes only in the long-term. Among the tested scenarios, doing business as usual or continuing with the current condition results in the lowest outcomes.

Concerning better outcomes and sustainability this stresses the need to modify or adapt the CBWM program, with a stronger focus on *enhancing the commitment of local government actors through capacity buildings*: trainings, experience sharing, follow-up and technical support in the field, providing logistics, and allocating adequate budgets in the study area and other similar localities. Capacity building empowers local government actors to plan and more efficiently implement SWC structures in consultation with other actors, particularly farmers. These actors could motivate farmers through voluntary instruments, establish and strengthen micro-watersheds associations or devise other strategies for maintenance of SWC structures, and even contribute to the creation of local livelihood opportunities for the poorer farmers with other actors. More importantly, capacity building creates an opportunity to implement local need-based adaptations into the program, with actors who are capable to assess the limitations of the program and who feel more ownership and commitment.

6. Synthesis

6.1 General discussion

Land degradation, particularly soil erosion by water and soil fertility depletion have become the main obstacles for sustained agricultural production and productivity in Ethiopia (Rahmato and Assefa, 2006; Miheretu and Yimer, 2017). Land degradation has made large areas unsuitable for crop production, decreased agricultural productivity, increased poverty, and worsened food insecurity - especially in the Central Rift Valley (CRV) of Ethiopia (Meshesha et al., 2010; Meshesha et al., 2012). Successive governments of Ethiopia have introduced various land management interventions to respond to the problem of land degradation since the 1970s (Osman and Sauerborn, 2001; Adimassu et al., 2017). Some of these interventions are carried out through food-for-work payments or other incentives, while others are implemented through mass mobilization of farmers for campaign works. The latter approach was implemented at large scale during the *Derg* regime - a communist government that ruled Ethiopia between 1974 and 1991. However, this effort did not curb the problem in a meaningful and sustainable manner (Bewket and Sterk, 2002; Zeleke, 2006; Amsalu and De Graaff, 2006).

The current government has continued with campaign works as part of the national Campaign-Based Watershed Management (CBWM) program since 2011/12. The program is implemented at the level of and within the *Kebele* (village) administrative boundaries by means of mass mobilization of farmers without any form of remuneration, under the coordination of *Kebele* administrators and leaders of development teams, and with technical support of extension workers (Danano, 2010; Wolancho, 2015; Haregeweyn et al., 2015). The program involves identifying one or more micro-watersheds every year (private farmland, communal land) for collective action, implementing Soil and Water Conservation (SWC) activities through campaign works for 30 to 40 days, and ensuring maintenance of these activities by handing over the micro-watersheds on communal land and private farmland to micro-watershed associations and individual owners respectively.

The program has been considered successful in terms of farmers' labor contribution, and implementation of different SWC structures on a large area at low cost in a short period of time (Haregeweyn et al., 2015; Teshome et al., 2016a). However, recent studies show that the program mainly follows a top-down planning approach (Weldemariam et al., 2013; Snyder et al., 2014), in which farmers' needs, aspirations, and indigenous knowledge and practices are hardly considered (Mulema et al., 2017). This often leads to farmers' limited genuine participation in campaign works (Wolka, 2014; Wolancho, 2015) and lack of maintenance of the constructed SWC structures (Snyder et al., 2014; Jemberu et al., 2017).

Against this background, the overall objective of this thesis was to explore strategies that enhance the sustainability of the Campaign-Based Watershed Management program in the Boset District of Ethiopia. The study employed a participatory Agent-Based Modelling approach in Ararso-Bero, Sara-Areda, and Qachachule-Guja *Kebeles* of Boset District. It began with an in-depth analysis of the CBWM program using an empirical research, followed by the construction of an ABM and the exploration of scenarios. The results of these studies have been presented in the previous chapters of this thesis. In section 6.2 below, these results are synthesized and discussed. Section 6.3 reflects on the core issues emerging from the research findings. Section 6.4 and 6.5 present the implications of this study for policy-making and science respectively. Section 6.6 presents the limitations of the study and recommendations for future research. Finally, section 6.7 presents the overall conclusions of the thesis.

6.2 Main findings of the research

1) *Explain factors that affect farmers' decisions to participate in the planning, implementation, and post-implementation stages of the program (chapter 2)*

The aim of the first research objective was to analyze farmers' level of participation in the CBWM program and the factors that determine their participation. The results showed that farmers' level of participation in the CBWM program was quite low, but varied across the stages of the program. At the *planning stage*, local government actors rarely require or even invite farmers to participate. Consistent with other studies (e.g. Weldemariam et al., 2013; Snyder et al., 2014; Nigussie et al., 2018), the planning of the program follows a top-down approach and critical decisions are taken at higher governmental levels. As a result, plans rarely fit local contexts, creating a lack of ownership by local actors, particularly farmers (Ariti et al., 2018). The participation of farmers was highest at the *implementation stage*, in which all adult farmers are required to participate in campaign works. Similar to conclusions by Abi (2019), the main shortcomings of the campaign works have been a shortage of labor and working tools, a lack of follow-up or technical support by higher government authorities, low knowledge and commitment of local government actors, and use of coercive measures to mobilize farmers. Compared to other stages, the participation of farmers at the *post-implementation stage* was moderate. As was also shown by Snyder et al. (2014), actual maintenance of SWC structures constructed through campaign works is low, due to limited follow-up by higher government authorities and local government actors as well as poor institutional, financial and technical capacities of the micro-watershed associations. Three key factors were found to influence farmers' level of participation in the program, but with different effects across the studied *Kebeles* and stages of the program.

First, location or proximity to the micro-watersheds was a crucial factor influencing their participation at all stages of the program. In line with other studies, the level of participation was lower for farmers who were far away from micro-watersheds (Okumu and Muchapondwa, 2017) and seasonally migrate to other localities in search of off-farm employment (Dillon, 2011; Wang et al., 2016). *Second*, similar to the finding of Kacho and Asfaw (2014), farmers' level of participation (particularly at the post-implementation stage) was influenced by how they perceived the commitment of leaders of local networks. *Third*, as also shown by Ohno et al. (2010) and Abi et al. (2019), farmers' level of participation at all stages of the program was influenced by their awareness of watershed degradation and their motivation to act.

2) *Assess outcomes of the CBWM program and its effect on the willingness of farmers to participate in the upcoming program activities (chapter 3)*

The second research objective focused on assessing farmers' perception of the effects of the program, particularly the physical works and changes in biophysical and socio-economic conditions, and how this influences their willingness to participate in future activities. Results showed that in the farmers' perception the overall outcomes of the CBWM program were quite poor. As a result, farmers' perceived outcomes of the program hardly motivated them to participate in the program. Though farmers were motivated to undertake trainings preceding campaign works and supported the construction of SWC structures on their farmland and the communal land they use, they were less motivated to contribute labor and working tools without pressure from local government actors. Farmers were least motivated by the economic effects of the program, because of the weakness or absence of micro-watershed associations (failure to reach the target group, poor maintenance of the SWC structures, lack of benefit-sharing mechanisms), and conflicts among farmers over access to micro-watersheds on communal land. Consistent with other studies (e.g. Bagherian et al., 2009; Agidew and Singh, 2018; Zeweld et al., 2018), farmers were also hardly motivated by the physical effects of the program. This was mainly due to the limited direct biophysical benefits of the program to individual farm households, and the destruction of practices in previously developed micro-watersheds by frequent runoff from neighboring *Kebeles* and human and animal disturbances. As shown also by Amsalu and de Graaff (2006) and Teshome et al. (2016a), the only motivating outcome of the program concerned its effect on personal capacities, which was particularly appreciated in localities that were vulnerable to erosion.

3) *Develop a Role-Playing Game to explore decision-making and mutual learning among actors in the program (chapter 4)*

By using a Role-Playing Game (RPG), the third research objective intended to analyze farmers' decision-making and learning and collective decision-making among local actors. The game was played using two scenarios: (1) a *default-scenario* or current condition - where *Kebele* administrators encourage (using awareness creation) and enforce (using reprimanding and punishing) farmers to participate in the program, and (2) a *willingness-scenario* - where the role of *Kebele* administrators is limited only to awareness creation. The results of the game showed that farmers preferred to collectively work on private farmlands in the downstream areas rather than on communal lands located in upstream areas, due to their lower awareness of the complexity of watershed degradation and its management, as well as lower motivation to invest in activities with uncertain future benefits, supporting findings by Gebremeskel et al. (2018). It also shows that the participation of farmers in campaign works was higher under the default-scenario than under the willingness-scenario, indicating lower motivation of farmers to contribute labor without more stringent measures, as also shown by Abi et al. (2019). However, maintenance of the SWC structures was more or less the same under the default-scenario and willingness-scenario, because of limited use of more stringent measures under the default-scenario. Farmers' participation in campaign works and their maintenance decisions were influenced by their location or proximity to micro-watersheds, i.e. distance from micro-watersheds and out-migration from *Kebeles* for off-farm or non-farm employment, as also found by Biratu and Asmamaw (2016). In addition, consistent with the findings of Dolisca et al. (2006), the awareness and motivation of farmers were crucial factors influencing their participation. Furthermore, as shown by Wesselow and Stoll-Kleemann (2017), the participation of farmers in campaign works was influenced by the decision of fellow farmers they considered more knowledgeable. Finally, the commitment of *Kebele* administrators was crucial to encourage and enforce farmers to participate in the program. However, farmers tended to respond better to more stringent measures than less stringent ones, indicating limited contribution of the ongoing awareness raising trainings of the CBWM program to enhance intrinsic motivation and sense of ownership among farmers (Leta et al., 2018). The results showed that the two scenarios will not simultaneously enhance both area of land covered with SWC structures and farmers' income. Nevertheless, the game enabled the actors to learn perspectives of one another on limitations of the program, to make collective decisions on locations of new micro-watersheds, and to explore alternative management strategies.

4) *Develop an Agent-Based Model and conduct scenario analysis to identify strategies that enhance the outcomes of the program (chapter 5)*

The fourth research objective aimed at exploring conditions that enhance the outcomes of the CBWM program by using an empirically-based ABM. The model analyzed the extent to which six scenarios (doing business as usual, motivating farmers, establishing and strengthening micro-watershed associations, introducing alternative livelihood opportunities for the poorer farmers, enhancing the commitment of local government actors, and integrating multiple interventions by jointly considering all previous alternative scenarios) enhance the area of land covered with SWC structures and their quality. The scenario analysis revealed that integrating multiple interventions results in best outcomes. This confirms the widely held views that watershed management initiatives should not only focus on conservation of natural resources, but also on building the capacity of local institutions and livelihood of the people concerned (Kerr, 2002; Shiferaw et al., 2009; Leta et al., 2018). However, integrating multiple interventions would require huge resources and collaboration among various actors, which is lacking in the current CBWM program in the country (Abi, 2019). A more efficient strategy is to focus only on enhancing the commitment of local government actors through capacity building, since this scenario produces reasonable outcomes and yet requires lower investment. Similar to integrating multiple interventions, this strategy has spillover effects, empowers local government actors, enhances maintenance of SWC structures, particularly on communal land, and generates better outcomes both in the short-term and long-term. This confirms the significance of enhancing local governance in collective watershed management initiatives (Araral, 2009; Ratner et al., 2013; Nagendra and Ostrom, 2014; Nigussie et al., 2018), hence also in the CBWM program (Wolancho, 2015). Motivating farmers, as well as establishing and strengthening micro-watershed associations, are important where the performance of local government actors is strong, and where initial awareness and motivation of farmers is low. Introducing alternative livelihood opportunities is crucial where poorer farmers seasonally migrate to other localities for off-farm employment. However, all alternative scenarios have some added value compared to doing business as usual. This means that in order to achieve better outcomes and more sustainability, there is a need to modify or adapt the current program by considering different local contexts.

6.3 How to improve the CBWM program in Ethiopia?

This part reflects on key points drawn from the findings of the research and their significance to enhance outcomes and sustainability of the CBWM program.

First, the findings from chapter 2 indicate that the planning of the CBWM program follows a top-down approach, where higher government authorities make almost all decisions and farmers' participation is believed to be ensured by inviting them to embrace and implement plans prepared by higher government authorities in a training session preceding the campaign works. As a result, plans rarely fit local contexts, creating lack of ownership by local actors. This calls for *a more participatory planning of the program* in Ethiopia. Participatory planning empowers local actors to consider locally variable socio-economic conditions (knowledge, views, aspirations, needs) and biophysical conditions (location, soil type, slope, and land use) (chapter 2, chapter 4). Participatory planning furthermore enhances mutual learning and collective decisions among local actors (chapter 4), ensures more effective maintenance of the SWC structures and benefit-sharing mechanisms (chapter 3), and develops a sense of ownership of the program among farmers (chapter 2, chapter 4).

Second, the findings from chapter 2 and chapter 4 indicate that participation in the program activities is lower for farmers that seasonally migrate to other localities in search of off-farm and non-farm employments. This calls for the need to apply *a more integrated approach* to diversify program activities for better local livelihood opportunities. In this regard, the program should focus both on conservation of natural resources and on income generation for farmers, particularly in relatively poorer communities where farmers are forced to temporarily migrate to other localities in search of means of livelihood (chapter 2, chapter 5). Local livelihood opportunities could be created by developing more effective area closure initiatives of the micro-watersheds on communal land and handing them over to the seasonal migrants to benefit from restoration outcomes. Also, local livelihood opportunities could be created by targeting seasonal migrants where the Productive Safety Net Program is being implemented, or by collaborating with sector offices and Non-Governmental Organizations working on poverty reduction and food security.

Third, farmers' awareness of watershed degradation as well as their motivation to participate were crucial factors influencing their participation in the program (chapters 2-5). This suggests the need to *motivate farmers through capacity building* to enhance the outcomes and sustainability of the program. Capacity building of farmers should include intrinsically motivating them through awareness raising, literacy education, and capacity building of local organizations so that these organizations engage in collective actions, facilitate mutual trust and networks, and empower farmers to participate in the program's decision-making processes (chapter 2). However, the focus of this intervention should be on model farmers and influential individuals, since farmers follow the decisions of more dynamic and intrinsically motivated farmers (chapter 4). Capacity building not only motivates farmers to participate in the campaign works and maintenance of the SWC structures, but also empowers them to effectively participate in the participatory planning process and contribute to the spontaneous spreading of the SWC structures since this improves farmers' knowledge and skills (chapter 3, Abi et al., 2018b).

Fourth, findings from chapter 2, 4 and 5 indicate that the commitment of local government actors (extension workers and *Kebele* administrators) is indispensable to encourage (using awareness creation) and enforce (using reprimanding and punishing) farmers to participate in the program, as well as to give technical support in the field. Hence, it is essential to *enhance the commitment of local government actors through capacity building*, with a focus on trainings, experience sharing, follow-up and technical support in the field, as well as by providing logistics and adequate budgets. Capacity building of local government actors will develop their sense of ownership of the program and empower them to plan and more efficiently implement the program in consultation with other local actors, particularly farmers. This means capacity building of local government actors is a prerequisite to introduce participatory planning and implement locally sensitive need-based adaptations of the program. In addition, capacity building enables local government actors to motivate farmers through voluntary instruments (mutual learning and information exchange) and apply a more integrated approach by including alternative local livelihood opportunities.

Table 6.1 *Summary of the relationship between chapters and conclusions.*

Chapters	Conclusions			
	More participatory planning	Apply a more integrated approach	Motivate farmers through capacity building	Enhance commitment of local government actors
Chapter 2: Factors affecting farmers' participation in the program	√	√	√	√
Chapter 3: Outcomes of the program and its effect on farmers' willingness to participate	√	-	√	-
Chapter 4: Farmers' decision-making, and learning and collective decisions among actors	√	√	√	√
Chapter 5: Conditions that enhance the outcomes of the program	-	√	√	√

In conclusion, participatory planning, applying a more integrated approach, motivating farmers, and enhancing the commitment of local government actors are four key interventions to improve the CBWM program (Table 6.1). These interventions point to the importance of implementing a participatory integrated watershed management approach in the program. Such an approach emphasizes participatory processes in terms of the issues to be worked on and how they are carried out, and the integration of disciplines (technical, social and institutional dimensions) or objectives (conservation, food security, income generation) (Meinzen-Dick et al., 2002; German et al., 2007; Darghouth, et al., 2008). The significance of motivating farmers and enhancing the commitment of local government actors suggests the need to focus on community empowerment within this approach. Considering the fact that the community is a social entity, empowerment should include capacity building and strengthening in various dimensions. However, given the diversity in the physical and socio-economic environments, any effort to community empowerment should be locally sensitive. Once empowered, communities can effectively participate in the participatory planning processes and collaborate with other actors to apply a more integrated approach.

However, the follow-up question is: what objective conditions or opportunities are already present to start implementing a participatory integrated watershed management approach in the CBWM program in Ethiopia? The first opportunity is the existence of "community-based participatory watershed development guidelines" that promote the improvement of rural livelihoods through comprehensive and integrated natural resource development (Desta et al., 2005; MoARD 2008). These guidelines are essentially prepared to provide a workable and adaptable planning tool to the District and local level actors. Hence, they could be used as an entry point to promote a participatory integrated watershed management approach in the CBWM program. The second opportunity is the existence of organizational structures for the planning and implementation of the program, including: 1) Federal to local level administrative structures and agricultural and natural resources offices; 2) sustainable land management steering committees and technical committees at all institutional levels; and 3) community organizations in the *Kebeles* (development teams, and local networks). If used wisely, there is a potential to build institutional collaboration and bring together different actors to exchange knowledge and expertise, mobilize resources, and apply an integrated approach (Yirga et al., 2014). The third opportunity is the apparent farmers' willingness – as found in this study – to undertake trainings to improve their knowledge and skills on activities that were implemented during campaign works and support the construction of SWC structures on their farmland and the communal land they use (chapter 2). This could be used as a starting point to create intrinsic motivation among farmers by using voluntary instruments, such as mutual learning and information exchanges, as well as facilitate the spontaneous spreading of SWC structures.

However, currently, the top-down approach of Federal and Regional government officials is a main challenge to the implementation of participatory integrated watershed management in the CBWM program at the local level. Higher governmental officials push for the implementation of over-ambitious plans that don't fit local contexts (chapter 2), and therefore have been rarely taken up and implemented at the *Kebele* levels. As a result, local government actors often submit exaggerated reports to the higher government authorities (chapter 2), because higher government authorities hardly discourage and rather reward dishonest individuals who misreport at the expense of honest ones (Nigussie et al. 2018). Undoubtedly, this malpractice not only debilitates the outcomes, ownership and sustainability of the program, but also affects the motivation of farmers for future collective action initiatives. In this regard, implementing a participatory integrated watershed management approach in the CBWM program should commence from changing the mindset of higher-level government actors (chapter 2) so that they give room for experts and the community to plan and implement the program in their localities.

Finally, the study shows that the sustainability of the SWC structures and tree seedlings planted in previously developed micro-watersheds is often compromised by the frequent runoff from neighboring *Kebeles* (chapter 3). Hence, integration of actions at watershed level is crucial to come to effective water runoff control and collaboration between neighboring *Kebeles* in watersheds. This means that the implementation of participatory integrated watershed management at the local level should be accompanied by integration of plans at the District or Regional levels. Here local supervisors, experts and authorities in the District and Regions could play a pivotal role in integrating plans at watershed level.

6.4 Policy implications

The research aimed at understanding the CBWM program and exploring strategies that ensure more sustainable impact in the Boset District of Ethiopia. The findings of the research suggest that introducing a more participatory planning approach (chapter 2, 3 and 4), motivating farmers through capacity building (chapter 2-5), applying a more integrated approach (chapter 2, 4 and 5), and enhancing the commitment of local government actors through capacity building (chapter 2, 4 and 5) are crucial to enhance the outcomes and sustainability of the program (Table 6.1). In this regard, the results of the study are invaluable for the CBWM program actors at the Federal, Regional, District, and *Kebele* levels to plan and implement the program for better outcomes and sustainability.

From a practical point of view, the Federal Ministry of Agriculture and Natural Resources as an institution leading and coordinating the CBWM program at the national level could use the results of the study to examine limitations of the current top-down planning of the program, prepare a training manual to build the capacity of Regional actors, develop and implement a more participatory monitoring and evaluation of the program, and devise national direction for the collaboration of sector offices. In addition, the Ministry could give trainings to Regional Bureaus (who are responsible for planning) on how to use both RPGs and ABM for mutual learning and for exploring alternative strategies at the local level.

Furthermore, the Oromia Region Agriculture and Natural Resource Bureau for its part could learn from the limitations of the program revealed by this research, how these limitations affect the outcomes and sustainability of the program, and devise alternative strategies to enhance the outcomes and sustainability of the program. In this regard, experts and decision-makers could use the results of the study as an input to make more comprehensive or feasible annual plans in their jurisdiction. A good start is to hold discussions and support Boset District and *Kebele* level actors to implement strategies suggested for the studied *Kebeles*. They could also use the RPG and ABM as a training tool for the District level actors. Furthermore, the Regional and District level experts could collaborate to implement the RPG and ABM to explore locally sensitive management options in selected pilot *Kebeles*.

6.5 Contribution to science

The study aimed at understanding the CBWM program and exploring strategies that ensure more sustainable impact. A Participatory Agent-Based Modelling Approach was used to involve the views of actors in the modelling as well as in the scenario exploration processes. It began with an in-depth analysis of the CBWM program, and an attempt was made to gain insight into decision-making of actors and their interactions (chapter 2). To this end, Ostrom's (2005) Institutional Analysis and Development (IAD) framework was adapted and tested in the context of the CBWM program. In addition, a novel conceptual framework was developed to explain how different outcomes of the CBWM program are related to each other, and how this influences farmers' willingness to participate in the upcoming program activities (chapter 3). The study also developed and employed a RPG to further explore farmers' decision-making, as well as learning and collective decisions among actors (chapter 4). The use of RPGs in this way proved very useful, and is a novel approach used in this thesis. In general, the study incrementally employed multiple methods to understand the CBWM program and explore possible management options that enhance the outcomes and sustainability of the program. This approach grounds the construction of the ABM on real-world data, as such becoming a model that reflects the CBWM and can be used to conduct scenario analysis (chapter 5). Such models are unavailable in the existing literature. The thesis contributes to science with this novel approach, given that both the RPG and ABM were developed from scratch. This is particularly important in Ethiopia, where Participatory

Agent-Based Modelling has not been used before and where it can facilitate the integration of scientific and local knowledge for more sustainable watershed management.

The frameworks, the RPG, and the ABM could be used to further study the CBWM program and other mass mobilization initiatives in Ethiopia and other similar countries. The game (RPG) and the model (ABM) could be particularly useful to study social learning among actors of the CBWM program. Apart from using these tools for scenario analysis, and facilitate discussions, learning and negotiations among actors, they could be further developed or abstracted to test theories in the area of collective watershed management. Hence, the thesis is useful as a springboard for scientists and PhD students interested in analyzing complex socio-ecological systems in Ethiopia and other similar countries.

6.6 Limitations of the study and recommendations for future research

The study has the following key limitations. *First*, the study was conducted in only three adjacent *Kebeles* of Boset District for obvious shortage of time to cover additional areas. The main focus was to assess the performance of the CBWM program in localities that have broader agro-ecological and socio-economic similarity (chapter 1). However, exploring the experiences of different regions and agro-ecologies could help to gather a completer and more representative dataset at the Regional and National level. *Second*, though the study covered farmers' perceptions of the biophysical outcomes to assess how this influences their willingness to participate in the upcoming program activities (chapter 3), the *actual* biophysical impacts of the program were not measured. Hence, it is difficult to judge the success of the program without measuring the real effect of the program in terms of soil erosion control, soil fertility enhancement, moisture retention, and improved vegetation cover. *Third*, during the scenario analysis the study employed only two outcomes of the program: area of land covered with SWC structures and the quality of these SWC structures. The effects of the program on indirect biophysical outcomes (e.g. agricultural production and productivity, climate change mitigation and adaptation) are not included. More importantly, the study didn't analyze the effect of different scenarios on socio-economic outcomes for the farmers, such as food security, income, social cohesion, and social inequality. *Finally*, the study explored the significance of alternative scenarios or strategies that were identified through participatory processes to enhance the outcomes of the program compared to a default-scenario or doing business as usual (chapter 5). However, the result of the scenario analysis was not used in actors' workshops to enhance discussions, social learning and collective decisions on feasible management options. In order to improve the contributions of the research, the following recommendations are suggested for future research.

1. Measure the actual biophysical outcomes of the program, focusing on the effects of the program on soil erosion, soil fertility, moisture retention, vegetation cover, agricultural production and productivity. This is important to understand the shortcomings of the program more quantitatively and justify the importance of adapting the program for better outcomes and sustainability. Such data are also crucial to further calibrate and validate the ABM.
2. Use the ABM to analyze the effect of scenarios on socio-economic outcomes (e.g. climate change mitigation and adaptation, food security, income, social cohesion, and social inequality) of farmers. This is crucial to analyze and adopt scenarios that enhance both socio-economic conditions and biophysical conditions for sustainable watershed management.
3. Assess the effects of the participatory deployment of the ABM on enhancing social learning and collective decision-making among actors. This is essential to bring together actors at Local, District, and Regional levels to discuss, understand perspectives of one another, and collectively compare, evaluate, and select alternative scenarios for a more feasible management strategy that satisfies the interests of the actors.
4. Conduct a capacity assessment of key actors and sector offices to prepare plans for better collaboration among neighboring *Kebeles* and integration of livelihood activities. Coordination in watershed management is essential since this work is inherently multi-sectoral and many other agencies in the same watershed are conducting work that may also be closely related. Hence, capacity assessment is essential to identify key actors and their resources as well as to minimize problems of coordination.

6.7 Overall conclusions

This study provided insight into the national CBWM program of Ethiopia and explored strategies that ensure more sustainable impact, using a Participatory Agent-Based Modelling approach. The results of the study show that the program has a number of limitations, including a top-down planning approach, low awareness and motivation of farmers to participate in the program, poor commitment of local government actors to mobilize and give technical support for farmers, focus on the construction of Soil and Water Conservation (SWC) structures while giving less attention to rural livelihoods, and little attention to the maintenance of SWC structures in the developed micro-watersheds.

In order to tackle these limitations, the study suggested the need to implement a participatory integrated watershed management approach at the local level, by focusing on locally sensitive community empowerment schemes. In so doing, it recommends the need to (1) introduce a participatory or bottom-up planning approach so that local actors plan and implement the program in their respective *Kebeles*, (2) apply a more integrated approach by including local livelihood opportunities, (3) intrinsically motivate farmers through capacity building, and (4) enhance the commitment of local government actors through capacity building.

However, given the exposure of SWC structures to frequent runoff from neighboring *Kebeles*, the study suggests that the implementation of participatory integrated watershed management at the local level should be accompanied by integration of plans at the District or Regional levels. In addition, to implement this approach in the CBWM program, a change in the top-down mindset of higher-level government authorities is recommended; this will give room for local experts and the community to plan and implement better adjusted programs in their localities. Both the importance of integration among *Kebeles* and change in mindset of higher-level government authorities confirm the need to improve the governance of the CBWM program at different levels.

The thesis contributes to the literature on watershed management by exploring conditions that enhance the outcomes and sustainability of a collective action initiative. More importantly, the thesis has developed a conceptual framework, RPG, and ABM that can be used as a toolkit to further analyze the CBWM program and other similar collective watershed management initiatives and support their improvement.

Appendices

Appendix 1: Description of the Role-Playing Game

Appendix 1.1: Game setup

Before starting the game sessions, game materials were classified and arranged to smoothly facilitate the sessions. Blank flip charts were posted on the wall to report game outcomes, i.e. lengths of SWC structures (km) and area of land covered with SWC structures (ha) at each time step. The game board or map was placed in a visible place for all actors to facilitate selection of new micro-watersheds. *Kebele* administrators, extension workers, and leaders of development teams were asked to sit on one side, while the farmers were asked to sit on the other side. The moderator sat next to the two boxes to easily collect decision cards and calculate outcomes. Where important, the facilitator assisted the moderator and guided the game participants throughout the game sessions. The camerawoman record audio and visual data in the game session.

This is followed by the description of the game and distribution of materials to the game participants. The moderator informed the participants that the game represents activities that they carry out in the CBWM program. He then stated the objectives of the game, which is to understand how farmers actually behave in campaign works and after, and to identify more sustainable management option. Finally, the roles and responsibilities of the game participants were described. The participants were finally asked to reflect on the similarity between their actual roles and responsibilities and those introduced in the game.

Appendix 1.2: Activities at the playing stage at each time step

No.	Activities	Minutes		
		Default-scenario	Willingness-scenario	Total
1	Extension workers invite farmers to mark their preferred location of new micro-watersheds on the maps. Actors discuss, negotiate, and decide on the location of the new micro-watershed/s.	10	-	10
2	*Kebele* administrator orders farmers to make decision on their level of participation in campaign works (0 to 10). Farmer' choose and put a number that best indicates their level of participation in a box.	3	3	6

3	The leader of development team may/may not inspect decision of farmers to identify dissenters. Even so, he may/may not report names of absentees to *Kebele* administrator.	2	2	4
4	If leader of development team reports name of absentees, *Kebele* administrator take measures.	2	2	4
5	The facilitator determines income of each farmer based on their level of participation in campaign works.	2	2	4
6	The moderator calculates average campaign score (*C*) and length of SWC structures (*Lc*).	2	2	4
7	The *Kebele* administrator asks farmers to make maintenance decisions by choosing among "maintain", "ignore" or "demolish" options and put a card that best represents their choices in another box.	3	3	6
8	The leader of development team may/may not inspect decision of farmers to identify dissenters. Even so, he may/may not report names of absentees to *Kebele* administrator.	2	2	4
9	If leader of development team report name of absentees, *Kebele* administrator take measures	2	2	4
10	The facilitator calculates total income of each farmer.	2	2	4
Total		30	20	50

Appendix 1.3: Equations

Campaign score

The campaign score is an average of farmers level of participation in campaign works. The score is given as: $C = (\text{\# of players with a Lp} * \text{ Lp } + \cdots)/(\text{\# all players})$; where Lp refers to individual farmer's level of participation.

Maintenance score

The maintenance score is calculated by transforming farmer's decisions, i.e. "maintain", "ignore", or "demolish" to an average score. The "maintain" decision is assigned a weight of 10; while the "ignore" and "demolish" decisions are assigned weights of 5 and 0 respectively. The score is given as: $M = (\text{\# of players with a Md} * \text{Wd } + \cdots)/(\text{\# all players})$; where Md is a maintenance decision and Wd is weight attached to that decision.

Area of land covered with SWC structures (ha)

In order to estimate the area of land covered with SWC structures (*A)* at each time step, existing lengths of SWC structures in the micro-watersheds (*Le*), lengths of SWC structures constructed through campaign works (*Lc*), and maintenance score (*M*) are used.

Lc is calculated as: $Lc = \sum_{i=1}^{9} Ci * 0.003\ km$; where *Ci* and 0.003 km indicate campaign score of each farmer and estimated lengths of SWC structures that can be constructed with each campaign score. The total lengths of SWC structures (Lt) at each time step is determined as: $Lt = (Le + Lc) * M/10$.

Finally, Lt was converted to area of land covered with SWC structures: $A = (0.001\, km * Lt * 100)/0.15$ on communal land, and $A = (0.001\, km * Lt * 100)/0.11$ on farmland; where 0.001 km is width of SWC structures, 100 is to convert km^2 to ha, and the denominators, i.e. 0.15 and 0.11 indicate the recommended proportion of coverage of SWC structures on communal land and farmland respectively, as indicated by Teshome et al. (2013).

Average income (birr)

The average income (I) of farmers at each time step is a function of farmers' initial wealth status, participation level in campaign works, maintenance decisions, and income from SWC structures. It is given as: $I = (Iws + Ima + Iof + Mpb - Cpc - Cpp - Mpc - Mpp)/ \#\, of\ farmers$; where:

- *Initial wealth status (Iws)*: fake money representing wealth status; 1500 birr for the rich, 1000 birr for middle income, and 500 birr for poor.
- *Income from micro-watershed associations (Ima)*: Members of micro-watershed association receive 500 birr if their maintenance score is greater than average, i.e. five.
- *Income from own-farmland (Iof)*: Farmers whose farmland is with SWC structures receive 500 birr if his/her maintenance decision is "maintain" at this time step.
- *Campaign participation cost (Cpc)*: The higher farmer's level of participation in campaign works, the higher his/her participation cost. This is given as: $Cpc = ((farmer's\ level\ of\ participation)/10) * 500\ birr$; where 10 and 500 birr are maximum farmer's campaign participation score and maximum campaign participation cost respectively.
- *Campaign participation punishment (Cpp)*: A farmer whose level of participation in campaign works is considered to be lower by *Kebele* administrator will pay 100 birr as punishment.
- *Maintenance participation cost (Mpc)*: A farmer whose maintenance decision is "maintain" will lose 200 birr since this takes his labor away from his livelihood activities.
- *Maintenance participation punishment (Mpp)*: Punishment applies for farmers with "ignore" and "demolish" decisions when the *Kebele* administrator decides to punish. A member of a micro-watershed association with "ignore' decision will pay 50 birr as a punishment. Similarly, a farmer who decides to demolish the SWC structures will pay 100 birr as a punishment. However, there is no punishment for ignoring or destroying SWC structures on own private farmland.

- *Maintenance participation benefit (Mpb)*: Farmers who decide to "demolish" SWC structures from the micro-watersheds will receive 100 birr as additional income, because these farmers enter protected micro-watersheds to openly graze their cattle, and cut grasses and woods for private use.

Appendix 2: Description of the Agent-Based Model with ODD protocol, following Grimm *et al*. (2010)

2.1 Purposes

This model simulates the national CBWM program of Ethiopia to explore conditions that enhance coverage and quality of SWC structures. It analyzes the effect on the area of land covered and quality of SWC structures of (1) enhancing farmers' awareness and motivation, (2) establishing and strengthening micro-watershed associations, (3) introducing alternative livelihood opportunities, and (4) enhancing the commitment of local government actors.

2.2 Entities, state variables, and scales

This model includes three agents (farmers, *Kebele* administrator, extension workers) and the physical environment that interact with each other. The physical environment is represented by 1089 fields, and each field is equal to 0.25 ha. Table 1 illustrates static and dynamic state variables of the fields. The values of the state variables are determined based on empirical study conducted in the *Kebeles* (villages) (Assefa et al., 2018a).

Table 1 *State variables of the field.*

State variables	Values	Descriptions
Position (static)	Coordinates	-
Owned-by (static)	farmer code	Shows the farmer who owns this field.
Slope (static)	%	The topography of the landscape is diffused from highest slope to lowest at initialization.
Land-use (static)	farmland or communal land	Shows whether this field is in the farmland or communal land. It is assigned to fields based on slope, where all fields with slope > 30% is considered communal land.
Communal-micro-watershed? (dynamic)	true/false	Shows weather this field is inside the micro-watershed on communal land or not.
Farmland-micro-watershed? (dynamic)	true/false	Shows weather this field is inside the micro-watershed on farmland or not.
Communal-swc-cover? (dynamic)	true/false	Shows whether this field in micro-watersheds on communal land is covered with SWC structures or not.
Farmland-swc-cover? (dynamic)	true/false	Shows whether this field in micro-watersheds on farmland is covered with SWC structures or not.
Quality-SWC (dynamic)	0 -10	Shows initial quality of SWC structures.
Micro-watershed-name (static)	field code	Shows name of micro-watersheds. The initial micro-watersheds were named "initial" and subsequently newly selected micro-watersheds were named: 0, 1, 2, etc.

Farmers are created and randomly distributed to farmland. All farmers own farmland in their vicinity. Some are members of micro-watershed associations. Table 2 shows static and dynamic state variables of the farmers. The values of most state variables were assigned to farmers randomly based on normal distributions with mean and standard deviations collected from the *Kebeles* (Assefa et al., 2018a; Assefa et al., 2020).

Table 2 *State variables of farmers.*

State variables	Values	Descriptions
Position (static)	coordinates	Randomly distributed at initialization to fields on farmland.
Own-farmland (static)	patch-Id	Each farmer owns the fields or farmland in their vicinity; set based on average farm size of the three *Kebeles.*
Education (static)	0-10	Shows the class farmers completed (0 = Illiterate, 10 = 10 and above); randomly distributed at initialization.
Extent-off-farm-participation (static)	0-10	Shows the extent to which the farmer participates in off-farm activities; randomly distributed at initialization.
Degree-participation-local-organizations (static)	0-10	The extent to which the farmer participates in different local organizations; randomly distributed at initialization.
Perceived-performance-*kebele*-administrator (static)	0-10	Shows farmer's perception of the commitment of *Kebele* administrator; randomly distributed at initialization.
Income (dynamic)	>= 0	Initial wealth (stock) of the farmer (birr); randomly distributed at initialization.
Social capital (dynamic)	0-10	Shows the position or status of the farmer in the *Kebele*; randomly distributed at initialization.
Perception-watershed (dynamic)	0-10	Shows farmer's perception of the problem of watershed degradation and future benefits of the program; randomly distributed at initialization.
Membership-watershed-association (dynamic)	true / false	Shows whether this farmer is a member of micro-watershed association or not.
Commitment-member-micro-atersheds (dynamic)	0-10	Shows the commitment of members of micro-watershed associations; randomly distributed at initialization.
Measures (dynamic)	praise, no measure, aware, reprimand, punish	Shows the measure taken against this farmer by *Kebele* administrator. "No measure" at initialization.

The *Kebele* administrator has two static state variables: *position* (coordinates) and *commitment-of-kebele-administrator* (showing the commitment of *Kebele* administrator), ranging between 0 and 10. The extension workers have two similar static state variables: *position* (coordinates) and *commitment-extension-of-workers* (showing the commitment of the extension worker), ranging between 0 and 10. *Kebele* administrator and extension workers were placed around the center of the physical environment, and the values of their state variables (i.e. commitment) were set based on qualitative data obtained through key informant interviews (Assefa et al., 2018a) and Role-Playing game (Assefa et al., 2020).

The model also considers 36 system parameters with their default values and ranges (Table 3).

Table 3 *System parameters.*

No	Parameters	Default	Range	Functions
1	number-of-farmers	180	100 - 250	Initial number of farmers.
2	n-new-members-association	10	0 - 30	Number of farmers organized to form a new micro-watershed association every year.
3	maximum-participation-cost	600	300 - 1000	The amount of money (birr) a farmer loses because of his highest possible level of participation.
4	maximum-punishment	600	300 - 1000	The amount of money (birr) a farmer will be fined if he doesn't participate at all.
5	income-poor-threshold	500	0 - 1000	Money (birr) below which farmers are considered to be poor and eligible for alternative livelihood activity.
6	extension-workers-move-selection-threshold	3	0 - 10	Score above which extension workers move to attend meeting with other agents to select new micro-watershed.
7	extension-workers-selection-threshold	7	0 - 10	Score above which extension workers are able to enhance farmers' perception of watershed degradation and future benefits of the program.
8	*kebele*-administrators-move-selection-threshold	3	0 - 10	Score above which *Kebele* administrators move to attend meetings with other agents to select new micro-watershed.
9	*kebele*-administrators-selection-threshold	6	0 - 10	Score above which *Kebele* administrators oblige farmers to select their preferred type of micro-watershed (farmland vs communal land).
10	perception-watershed-move-selection	5	0 - 10	Score above which farmers move to attend meetings with other agents to select new micro-watersheds.
11	perception-watershed-selection-threshold	7	0 - 10	Score above which farmers decide to select their preferred type of micro-watershed (farmland vs communal land).
12*	w-perceived-performance-*kebele*-administrator-campaign	0.242	0 - 1	Relative influence of farmers' perceived performance of *Kebele* administrator during campaign participation.
13	w-off-farm-participation-campaign	0.385	0 - 1	Relative influence of the extent of participation in off-farm-activities during campaign participation.
14	w-distance-watershed-campaign	0.096	0 - 1	Relative influence of distance from micro-watersheds during campaign participation.
15	w-education-campaign	0.141	0 - 1	Relative influence of education during campaign participation.
16	w-social-capital-campaign	0.085	0 - 1	Relative influence of social capital during campaign participation.
17	w-degree-participation-local-organizations-campaign	0.039	0 – 1	Relative influence of degree of participation in local organizations during campaign participation.
18*	w-perception-watershed-campaign	0.012	0 - 1	Relative influence of perception of watershed degradation and future benefits of the program during campaign works.
19	extension-workers-move-campaign-threshold	5	0 - 10	Score above which extension workers move to newly selected micro-watershed during campaign participation.
20	*kebele*-administrators-move-campaign-threshold	7	0 - 10	Score above which *Kebele* administrators move to newly selected micro-watershed during campaign participation.
21**	w-perceived-performance-*kebele*-administrator-maintenance	0.289	0 - 1	Relative influence of farmers' perceived performance of *Kebele* administrator during maintenance participation.
22	w-off-farm-participation-maintenance	0.385	0 - 1	Relative influence of extent of participation in off-farm activities during maintenance activities.

23	w-distance-watershed-maintenance	0.104	0 - 1	Relative influence of distance from micro-watersheds during maintenance participation.
24	w-degree-participation-local-organizations-maintenance	0.022	0 - 1	Relative influence of degree of participation in local organizations during maintenance participation.
25**	w-perception-watershed-maintenance	0.200	0 - 1	Relative influence of perception of watershed degradation and future benefits of the program during maintenance participation.
26	extension-workers-move-maintenance-threshold	8	0 - 10	Score above which extension workers move to already developed micro-watershed during maintenance participation.
27	*kebele*-administrators-move-maintenance-threshold	8	0 - 10	Score above which *Kebele* administrators move to already developed micro-watershed during maintenance participation.
28	maintenance-threshold	9	5 - 10	Score above which farmers decide to maintain SWC structures.
29	demolition-threshold	3	0 - 5	Score below which farmers decide to demolish SWC structures.
30	min-members-commitment-threshold	3	0 – 5	Level of commitment of members of micro-watershed associations below which campaign and maintenance participations is relatively lower.
31	max-members-commitment-threshold	8	5 – 10	Level of commitment of members of micro-watershed associations above which campaign and maintenance participations is relatively higher.
32	min-social-relation-threshold	3	0 – 5	Level of social relation below which commitment of members of micro-watershed associations is relatively lower.
33	max-social-relation-threshold	8	5 – 10	Level of social relation above which commitment of members of micro-watershed associations is relatively higher.
34	chance-measure-campaign	80	50 – 100	Probability that *Kebele* administrators take measures during campaign participation.
35	chance-measure-maintenance	90	50 – 100	Probability that *Kebele* administrators take measures during maintenance participation.
36	perception-influence-neighbor-threshold	9	0 - 10	The level of farmers' perception of watershed degradation and future benefits of the program above which he/she directly influences neighbors' campaign participation.

*The sum from number 12 to 18 is 1. **Similarly the sum from number 21 to 25 is 1.

The simulation will run for 25 time steps and each time step is equal to one year. This is based on the actual design and implementation of the CBWM program activities, i.e. basic processes of the program are carried out within a year.

2.3 Process overview and scheduling

This part provides the *setup* and *go* procedures in the model.

2.3.1 Setup

- *Setup of human agents and their initial locations*

- Create farmers (member of micro-watershed associations, non-members) and randomly distribute to farmlands.
- Create extension workers and place around the center of the physical environment.
- Create *Kebele* administrators and place around the center of the physical environment.

- *Setup of physical environment*

Figure 1 shows steps followed to initialize the physical environment of the model.

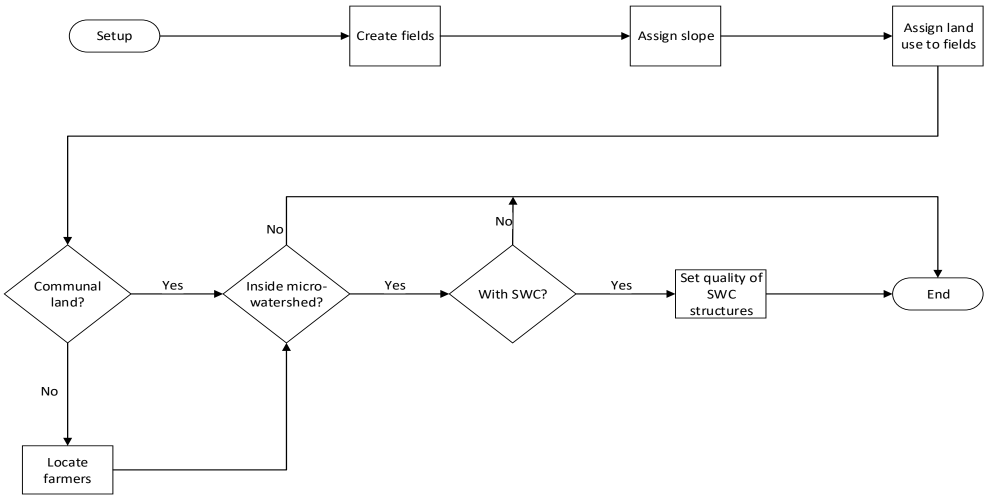

Figure 1 Flowchart of setup of physical environment.

- *Create fields*: The physical environment is made up of fields (each 0.25 ha).
- *Assign slope*: The topography of the landscape is diffused from highest slope to lowest at initialization.
- *Assign land use*: Fields with slope > 30 are considered communal land, while those that are =< 30 are considered farmland.
- *Establish micro-watersheds*: create clusters of fields to make micro-watersheds. The initial micro-watersheds are created considering their actual number and land uses in each *Kebele*.
- *Assign area of land with SWC structures*: Initialize area of land covered with SWC structures based on actual data collected from the *Kebeles*.
- *Set quality of SWC structures*: The initial quality of SWC structures (2015/16) is an average of 100 runs set in the calibration process, i.e. between 2011/12 and 2015/16. The model was initiated in 2011/12 and average *quality-SWC* in 2015/16 is taken as initial quality of SWC structures for scenario analysis.

2.3.2 Go procedure

The model has three key processes: (1) selection of new micro-watersheds to be developed, (2) construction of SWC structures through campaign works, and (3) maintenance decisions, where agents interact based on their roles and responsibilities.

Selection of new micro-watersheds to be developed: Every time step or year, the agents meet to select a new micro-watershed (Figure 2). The movement of farmers to the meeting center and their selection of technically viable (higher slope) fields depends on their *perception-watershed*. The movement of extension workers and *Kebele* administrator to the meeting center depends on their commitment. The main objective of extension workers is to improve the farmers' *perception-watershed* of the program so that they first select fields upstream (with steeper slopes). But the influence of extension workers depends on their commitment (*commitment-of-extension-workers*). The *Kebele* administrator also aims to ensure the selection of fields upstream, before proceeding to the lower areas. Depending on his/her commitment *(commitment-of-kebele-administrator*), he/she has the authority to enforce the selection of particular fields.

Construction of SWC structures through campaign works: During campaign works, the agents are expected to move to the newly selected micro-watershed to exert their responsibilities. Farmers whose *campaign-participation* is greater than zero randomly occupy fields in the selected micro-watershed to build SWC structures (Figure 2). They make decisions to participate in campaign works either due to their own attributes or by copying the decision of their neighbor with highest *perception-watershed* of the program. The extension workers randomly move in the selected micro-watershed to ensure the quality of SWC structures. At this stage, the *Kebele* administrator has dual roles: (1) take measures based on farmers' level of participation (campaign-participation), and (2) establish a new association when the micro-watershed is on communal land.

Maintenance decisions: Based on their attributes, farmers could either decide to "maintain" (maintenance-participation >= 8), "ignore" (3 < maintenance-participation < 8) or "demolish" (maintenance-participation =< 3) SWC structures (Figure 2). Farmers whose maintenance decision is "maintain" or "demolish" randomly move to the micro-watersheds to repair and remove the structures respectively. A farmer whose maintenance decision is "ignore" doesn't move. Ignored SWC structures decay overtime. At this stage, the extension workers and *Kebele* administrator randomly move across all micro-watersheds to ensure maintenance quality of SWC structures and to take measures based on farmers' decisions (maintenance-participation) respectively. The movement of both extension workers and *Kebele* administrators depends on their commitment.

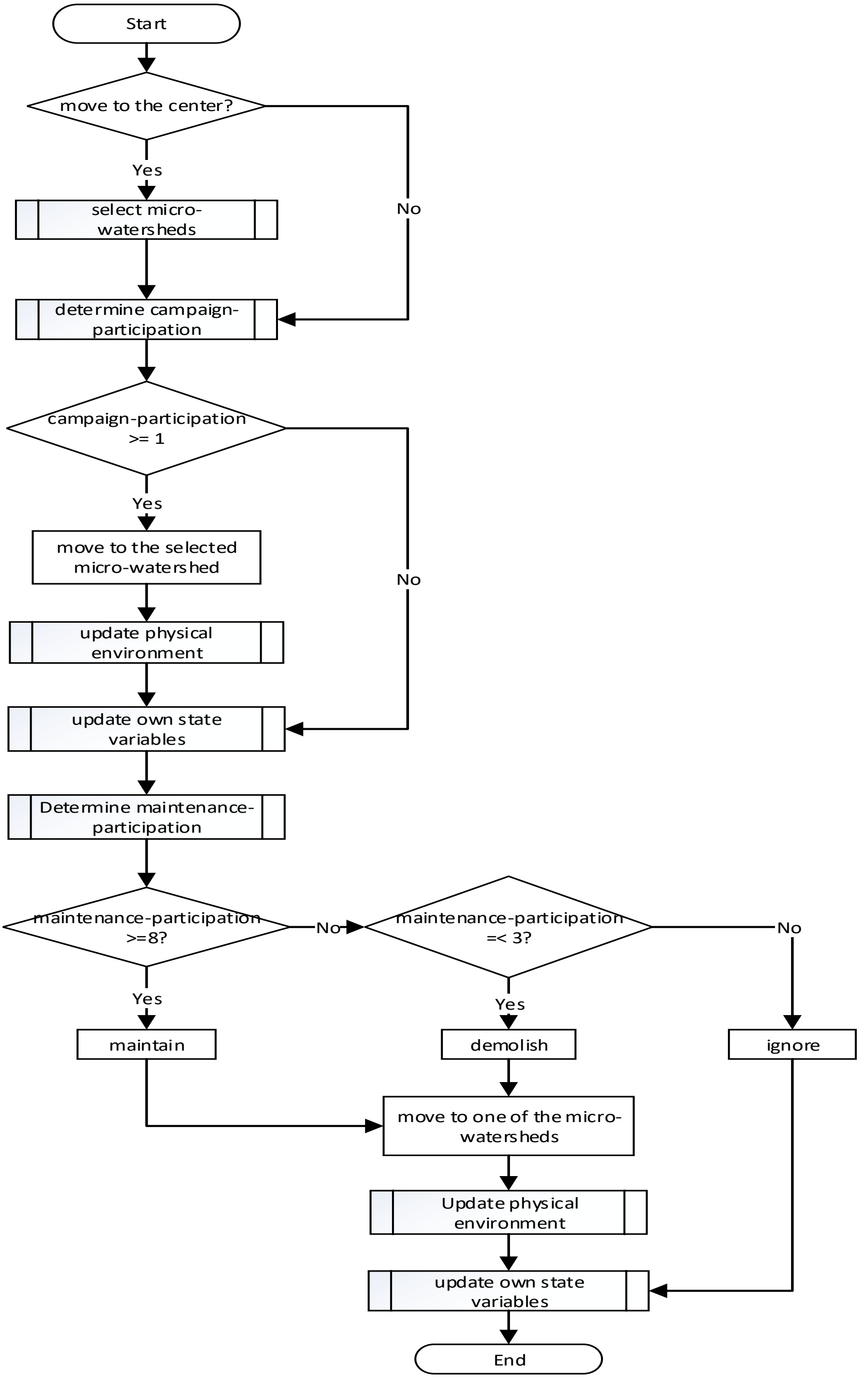

Figure 2: Flowchart of farmers decision-making behavior in the model.

2.4 Design concepts

2.4.1 Basic principles

This model simulates the CBWM program of Ethiopia to explore conditions that enhance coverage and quality of SWC structures. It shows how enhancing farmers' awareness and motivation, establishing and strengthening micro-watershed associations, introducing alternative livelihood opportunities, and enhancing the commitment of local government actors affect area of land covered and quality of SWC structures. Though crucial, similar model is lacking in the available literature. The model is developed from scratch using empirical data collected from three *Kebeles* that vary in terms of their performance in the CBWM program. This paves the way to develop a middle range model in its level of abstraction. Such models can easily be used to simulate the CBWM program and other similar collective watershed management in other similar localities.

2.4.2 Emergence

The model has two outcomes: (1) area of land covered with SWC structures and (2) quality of the SWC structures.

2.4.3 Adaptation

In addition to their own attributes, the decision of farmers to participate in campaign works is directly influenced by the decision of neighboring farmer with higher *perception-watershed*. Farmers also consider commitment and presence (nearness) of *Kebele* administrators and extension workers in their decision. More importantly, dynamic state variables of farmers are updated based on the their decisions, which affect subsequent decisions.

2.4.4 Objectives

Farmers are the most important agent in this model. They have individual objectives of maximizing income and social capital as well as collective objectives of participating in the CBWM program by selecting new micro-watersheds, construct SWC structures during campaign works, and maintaining the constructed structures. As shown in sub-section 2.1.3.2, *Kebele* administrators seek the selection of higher slope fields first as well as farmers' higher campaign-participation and maintenance-participation. Similarly, extension workers aim at ensuring the selection of higher slope fields and quality construction of SWC structures.

2.4.5 Sensing

Farmers sense their attributes to make decisions. They also sense perception-watershed of neighbors with highest score to copy their campaign-participation. Farmers are designed to sense all attributes of fields to make decisions: owners of the field, slope, land-use, micro-watersheds, fields with SWC structures, quality of the SWC structures, and micro-watershed name. They also sense the current commitment-of-*kebele*-administrator, previous measure taken against them due to their decision, and presence of extension workers in their vicinity.

2.4.6 Interaction

The decision of farmers is influenced by their own attributes and physical environment as well as influences of *Kebele* administrator and extension workers. There is unidirectional (extension workers and farmers, *Kebele* administrator and farmers) and reflexive (interaction among farmers) relationships among agents. The relationship between farmers and fields is bidirectional.

2.4.7 Stochasticity

At each time step, the model setup uses random seed to generate unique numbers at initialization. As empirically-based model, the values of most state variables were assigned to farmers randomly based on normal distributions with mean and standard deviations. Similarly, most state variables of the fields were randomly assigned based on data collected from the *Kebeles*. In addition, some system parameters are either drawn from empirical probability distributions or set based on calibration processes.

2.4.8 Observation

The NetLogo interface shows the physical environment and agents. In addition, plots are used to visualize area of land covered and quality of SWC structures overtime.

2.5 Initialization

The interference of the model has three *Kebeles* (case studies). One can easily select case study name to initialize particular *Kebele*. Farmers, extension workers, and *Kebele* administrator as well as physical environment are initialized when the model starts. The initial number of farmers (number-of-farmers) can be adjusted using slider, and randomly distributed to the fields on farmland. *Kebele* administrator and extension workers are placed near to the center, and the values of their state variables can be adjusted using sliders. State variables of farmers and fields can also be easily adjusted from slider.

2.6 Input data

The model do not have external input.

2.7 Sub models

2.7.1 Selection of new micro-watersheds

Figure 3 shows how farmers' make decisions to select new micro-watersheds by interacting with extension workers and *Kebele* administrators.

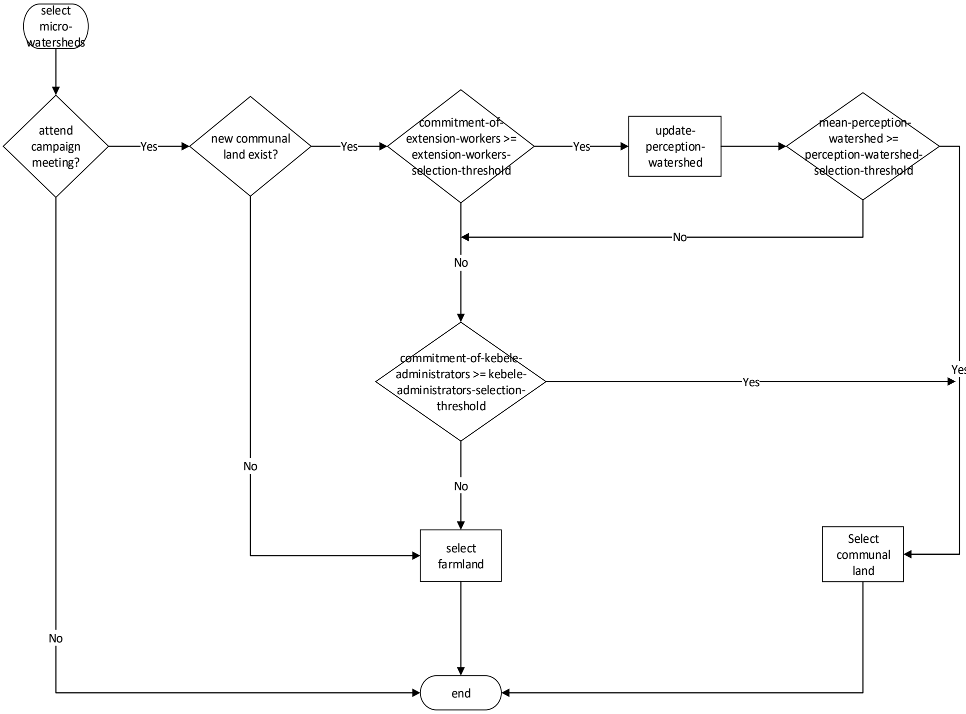

Figure 3 Flowchart of farmers' decision-making during the selection of new micro-watersheds.

- At each time step, farmers, extension workers, and *Kebele* administrator meet to select new micro-watersheds from either communal land or farmland. Farmers are expected to select micro-watersheds on communal land, before proceeding to farmland.
- Extension workers influence perception-watershed. However, the influence of the extension workers depends on their commitment (commitment-of-extension-workers). If commitment-of-extension-workers >= extension-workers-selection-threshold, the extension workers enhances farmers' perception-watershed. If mean-perception-watershed >= perception-watershed-selection-threshold, farmers will select communal land. This means extension workers aware farmers so that they select technically viable fields for campaign workers.
- However, *Kebele* administrator directly influences the decision of farmers, which again depends on his/her commitment (commitment-of-*kebele*-administrator). If

commitment-of-*kebele*-administrator >= *kebele*-administrators-selection-threshold, *Kebele* administrators will directly force farmers to select fields considered viable for campaign works at this time in point.

2.7.2 Determine campaign-participation (Pc):

Farmer's participation in campaign works is the result of two key factors: (1) effect of farmers own attributes and (2) effect of decision of neighbors. The first key factor includes seven factors that influence farmer's participation in campaign works, i.e. campaign-participation (Pc), which is given as:

Pc = perceived-performance-*kebele*-administrator * w-perceived-performance-*kebele*-administrator-campaign + (10 - extent-off-farm-participation) * w-off-farm-participation-campaign + (10 - distance-micro-watershed-campaign) * w-distance-watershed-campaign + education * w-education-campaign + degree-participation-local-organizations * w-degree-participation-local-organizations-campaign + social-capital * w-social-capital-campaign + perception-watershed * w-perception-watershed-campaign Eq.(1)

Distance-micro-watershed-campaign indicates distance between the farmer's position and the micro-watersheds selected for campaign works at this particular time-step. Pc is higher for members of micro-watershed associations. However, farmers directly copy Pc of a neighbor with highest awareness, i.e. perception-watershed >= 9. Pc of each farmer ranges between 0 and 10. Average Pc is calculated as:

$$\text{Average Pc} = \frac{\sum \text{Pc}}{\text{number-of-farmers}} \qquad \text{Eq.(2)}$$

2.7.3 Update physical environment due to campaign-participation

Area of land covered with SWC structures*:* Calculation of area of land covered with SWC structures was preceded by determination of lengths of SWC constructed through campaign works (lengths-SWC-campaign). Lengths-SWC-campaign = campaign-participation * 0.003. This means a farmer constructs 0.003 km for each campaign-participation score, which is assumed to be 3 work days. The total lengths of SWC structures constructed (total-lengths-SWC-campaign) by the farmers is sum of lengths-SWC-campaign. The area of communal land covered with SWC structures due to campaign works is given as:

$$\text{communal-SWC-cover-campaign} = \frac{0.001\ \text{km} * \text{total-lengths-SWC-campaign} * 100 * 4}{0.15\ \text{ha}} \qquad \text{Eq.(3)}$$

Similarly, the area of farmland covered with SWC structures due to campaign works is given as: $\text{farmland-SWC-cover-campaign} = \frac{0.001\ \text{km} * \text{total-lengths-SWC-campaign} * 100 * 4}{0.11\ \text{ha}}$ Eq.(4)

In both Eq.(3) and Eq.(4), 0.001 km is width of SWC structures, 100*4 is to convert km^2 to 0.25 ha, and 0.15 ha and 0.11 ha indicate average recommended SWC structures on communal land and farmland per hectare respectively. The area of land covered due to campaign-participation (i.e. communal-SWC-cover-campaign and farmland-SWC-cover-campaign), updates two state variables of fields: communal-swc-cover? and farmland-swc-cover?.

Quality of SWC structures: The quality of SWC structures that the farmers construct through campaign works depends on the presence of extension workers in their vicinity to give technical support. If extension workers are nearby, the quality-SWC will be 10, if not 9.

2.7.4 Update dynamic state variables of farmers due to campaign-participation

Perception-watershed and social-capital: Crucial to update farmer's perception-watershed and social-capital is measure taken against this farmer after campaign works. A measure taken by *Kebele* administrator is a function of his/her commitment (commitment-of-*kebele*-administrator), measure taken by *kebele* administrator at previous time step, and farmer's distance-from-average-participation (Pc - average Pc). If commitment-of-*kebele*-administrator >= *kebele*-administrators-move-campaign-threshold; the *Kebele* administrator will randomly move in the selected micro-watershed, take measures against farmers that update perception-watershed and social-capital. However, *Kebele* administrators do not always take measures. There is 90% chance that *Kebele* administrator takes *measures* that influence perception-watershed and social-capital.

Membership-watershed-association: The establishment of new micro-watershed association is dependent on the commitment-of-*kebele*-administrator and when the farmers select and develop micro-watershed on communal land. Hence, if commitment-of-*kebele*-administrator >= *kebele*-administrators-move-campaign-threshold and the new micro-watershed is on communal land; then select some farmers (n-new-members-association) randomly to be a member of new micro-watershed.

Income-campaign: Farmers participate in campaign works without any form of remuneration. Both their campaign-participation (Pc), and punishment have negative effect. Hence, income-campaign is given as:

$$\text{income-campaign} = -(\text{campaign-participation-cost} + \text{campaign-punishment-cost}) \quad \text{Eq.(5)}$$

$$\text{campaign-participation-cost} = \left(\frac{\text{Pc}}{10}\right) * \text{maximum-participation-cost; 10 is maximum Pc} \quad \text{Eq.(6)}$$

campaign-punishment-cost =

$$\text{maximum-punishment} - \left(\frac{Pc}{10} * \text{maximum-punishment}\right); \text{10 is maximum Pc} \qquad \text{Eq.(7)}$$

Perceived-performance-kebele-administrator: After campaign works, farmers evaluate performance of the *Kebele* administrator, by updating their perceived-performance-*kebele*-administrator. Farmers' update their perceived-performance-*kebele*-administrator by assessing commitment-of-*kebele*-administrator and average Pc of farmers.

2.7.5 Determine maintenance participation (Pm)

Maintenance of SWC structures involves labor contribution, strictly observing rules and regulations, and protecting micro-watersheds from disturbances. In this regard, all farmers make maintenance decisions on the already constructed structures. Farmer's participation in maintenance activities or maintenance-participation (*Pm*) (0-10) is the result of six factors.

Pm = perceived-performance-*kebele*-administrator * w-perceived-performance-*kebele*-administrator-maintenance + (10 - extent-off-farm-participation)* w-off-farm-participation-maintenance + (10 - distance-communal-watershed-maintenance)* w-distance-watershed-maintenance + degree-participation-local-organizations * w-degree-participation-local-organizations-maintenance + perception-watershed * w-perception-watershed-maintenance Eq.(8)

However, maintenance-participation is higher for members of micro-watershed associations. For convenience, Pm of each farmer is converted to three maintenance decisions: maintain (*Pm* >= 8), ignore (3 < *Pm* < 8), and demolish (*Pm* =< 3). The average maintenance-participation of the farmers is given as:

$$\text{Average Pm} = \frac{\sum \text{Pm}}{\text{number-of-farmers}} \qquad \text{Eq.(9)}$$

2.7.6 Update physical environment due to maintenance-participation

Area of land covered with SWC structures: The area of land covered with SWC structures at the end of each time step is the result of farmers' maintenance decision: "maintain", "ignore", or "demolish". This means maintenance decision update two state variables of fields: communal-swc-cover? and farmland-swc-cover?. Farmers with "maintain" decision contribute labor, strictly observe rules and regulations pertaining to maintenance of SWC structures (e.g. not directly destroying or exposing the structures for destruction), and protecting micro-watersheds from disturbances. However, labor contribution for maintenance of SWC structures on communal land is carried out only by members of micro-watershed associations, i.e. members maintain their own watershed (own-watershed). Farmers first maintain SWC structures with lower quality. Members also ensure area closure or guard micro-watersheds on communal land, but first own-watershed. Nonmembers, on the other hand, are expected to strictly observe rules and regulations pertaining to maintenance of SWC structures and protecting the micro-watersheds from disturbances. In other words, a highly motivated nonmembers also ensure area closure or guard micro-watersheds on communal land. However, each farmer is responsible for the maintenance of SWC structures constructed on his/her farmland (own-farmland). Ignored SWC structures decay overtime. Farmers with demolish decision remove SWC structures from fields, but starts with higher quality. The area of land covered with SWC structures was total number of fields with SWC-quality of at least 1. To determine area of land covered with SWC structures at the end of each time step in ha, the following code was used: count patches with [communal-SWC-cover? = true or farmland-SWC-cover? = true] / 4.

Quality of SWC structures: The quality of SWC structures changes based on the maintenance decision of farmers. Maintenance decision updates quality-SWC. If extension workers are nearby, a farmer with “maintain” decision set quality-SWC at 10, if not 9. The quality of ignored SWC structures decline by 1 every time step. A farmer with “demolish” decision, set quality-SWC 0. To calculate average quality-SWC at each time step, the following code was used: if any? patches with [communal-SWC-cover? = true or farmland-SWC-cover? = true] [plot mean [quality-SWC] of patches with [communal-SWC-cover? = true or farmland-SWC-cover? = true]]

2.7.7 Update dynamic state variables of farmers due to maintenance-participation

Perception-watershed and social-capital: After maintenance decision, farmer’s perception-watershed and social-capital are updated because of measures taken (measures) by *Kebele* administrator. Measures taken (measures) by *Kebele* administrators are functions of their commitment (commitment-of-*kebele*-administrator), measures taken (measures) by *kebele* administrator at previous time step, and distance-from-average-participation, which is given as: Pm – average Pm. If commitment-of-*kebele*-administrator >= *kebele*-administrator-move-maintenance-threshold; the *Kebele* administrator randomly moves throughout all micro-watersheds, take measures that update perception-watershed and social-capital. However, *Kebele* administrators do not always take measures. There is 80% chance that *Kebele* administrator take measures. In addition, confrontation between a farmer whose maintenance decision is “maintain” or ensuring area closure or guard micro-watersheds on communal land, and those with maintenance decision of “demolish” leads to a decline in social-capital of the latter.

Income: At the end of each time step, income is updated. Income is a function of income change due to campaign-participation (income-campaign), income change due to maintenance-participation (income-maintenance), income obtained from structures constructed on communal land as a member of micro-watershed association (income-own-watershed), and income obtained from farmland if SWC is constructed on own-farmland (income-own-farmland). These incomes are dependent on the SWC-quality of the fields. For income-campaign (see sub-section 7.4). Income-maintenance is determined based on maintenance decision of farmers. For farmers with maintenance decision "maintain", income-maintenance is given as:

income-maintenance =

$$-\left(\frac{\text{Pm}}{10}\right) * \text{maximum-participation-cost;10 is maximum Pm} \qquad \text{Eq.(10)}$$

For farmers that were punished by *Keble* administrator, i.e. measure = "punish", income-maintenance is given as:

income-maintenance = maximum-punishment - (Pm/10 * maximum-punishment);
10 is maximum Pm Eq.(11)

Off-farm-participation: At the end of each time step, farmer's level of off-farm-participation is updated based on his/her amount of income obtained from SWC structures, i.e. income-own-watershed and income-own-farmland. The more farmers obtain income from SWC structures, the more their participation in off-farm activities decreases.

Commitment-member-micro-watersheds: Farmers who are members of micro-watershed associations update their commitment, i.e. commitment-member-micro-watershed at the end of the time step. The commitment of a farmer is a function of his current perception-watershed, social-capital, and income-own-watershed.

Perceived-performance-kebele-administrator: Farmers update their perception of performance of *Kebele* administrators, i.e. perceived-performance-*kebele*-administrator at the end of each time step. Farmers update their perceived-performance-*kebele*-administrator by assessing commitment-of-*kebele*-administrator and average maintenance-participation of farmers.

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English summary

Successive governments of Ethiopia have introduced various land management interventions to respond to the problem of land degradation. Some of these interventions are carried out through food-for-work payments or other incentives, while others are implemented through campaign works. The latter approach, specifically the Campaign-Based Watershed Management (CBWM) program, has been implemented at large scale since 2011/12 by means of mass mobilization of farmers without any form of remuneration, under the coordination of *Kebele* (village) administrators and leaders of development teams, and with technical support of extension workers. The CBWM program involves identifying one or more micro-watersheds every year (private farmland, communal land) for collective action, implementing Soil and Water Conservation (SWC) structures through campaign works for 30 to 40 days, and ensuring maintenance by handing over the developed micro-watersheds on communal land to micro-watershed associations and private farmland to individual owners. The program has been considered successful in terms of farmers' labor contribution to the implementation of different SWC structures on a large area with low cost in a short period of time. However, recent studies show that the program has a number of limitations that often lead to farmers' limited genuine participation in the campaign works and maintenance of the constructed structures. Against this background, this thesis aims at exploring strategies that ensure more sustainable impact, using a Participatory Agent-Based Modelling approach.

First, the thesis analyzes farmers' level of participation in the CBWM program and the factors that determine their participation (chapter 2). The results show that farmers' level of participation in the CBWM program is quite low, but varies across the stages of the program. At the planning stage, local government actors rarely require or even invite farmers to participate. Rather, the planning of the program follows a top-down approach, where critical decisions are taken at higher governmental levels. The participation of farmers is highest at the implementation stage. Compared to other stages, the participation of farmers at the post-implementation stage is moderate. Using a Negative Binomial Regression Model (Maximum Likelihood Estimation), the study identified three key factors that influence farmers' level of participation in the program: location or proximity of farmers to the micro-watersheds, the commitment of local leaders, and awareness and motivation of farmers. These factors have differential effect across the studied *Kebeles* and stages of the program. The results of the study suggest the need to focus on smaller watersheds, enhance farmers' awareness and motivation through capacity building, include local livelihood opportunities, and enhance the commitment of local leaders. The chapter stresses the need to introduce

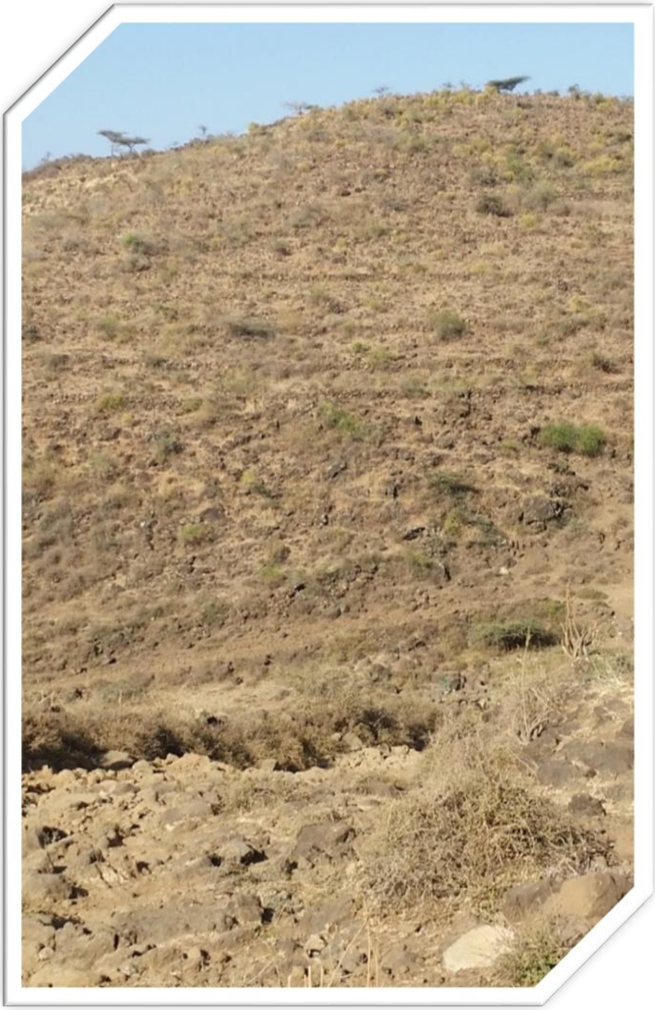
a more bottom-up planning in the CBWM program, given that the effect of these factors varies across the studied villages and stages of the program.

The thesis then assesses farmers' perception of the effects of the CBWM program, and how this influences their willingness to participate in future activities, using Spearman's partial correlation coefficients (chapter 3). Results show that farmers' perceived outcomes of the program hardly motivate them to participate in the program, because of (1) limited direct biophysical benefits to individual households, (2) the destruction of previously developed micro-watersheds by frequent runoff and human and animal disturbances, and (3) limitations/absence of benefit-sharing mechanisms and resultant conflicts among farmers. Farmers are more motivated by the effect of the program on their personal capacities (i.e. skills and acceptance of SWC structures), particularly in localities that are vulnerable to erosion. To enhance farmers' willingness in the program, this chapter suggests the need to better integrate actions at watershed level to effectively control water runoff, enhance the participation of all local actors to come to more effective area closure initiatives with transparent benefit-sharing mechanisms, and give much more emphasis to capacity building in the program.

In chapter 4, the thesis further analyzes farmers' decision-making behavior, and learning and collective decision-making among local actors, using a Role-Playing Game (RPG) that was developed based on results from chapters 2 and 3. The game is used to explore the effect of a default-scenario (current condition, where *Kebele* administrators use awareness creation, reprimanding, and punishments) and a willingness-scenario (where the role of *Kebele* administrators is limited only to awareness creation) on the area of land covered with SWC structures and income of farmers. Results show that farmers prefer to collectively work on private farmlands rather than on communal land. In addition, participation of farmers in campaign works is higher under a default-scenario than under a willingness-scenario. However, the participation of farmers in the maintenance of SWC structures is more or less the same under both scenarios. The location or proximity of farmers to the micro-watersheds to be treated, commitment of local government actors, and awareness and motivation of the farmers mostly influence farmers' decisions to participate in the program. Furthermore, farmers' level of participation in campaign works is influenced by the decision of fellow farmers who are considered more knowledgeable. The result of the game shows that none of the two scenarios simultaneously enhance area of land covered with SWC structures and income of farmers. The game is useful in stimulating mutual learning and collective decisions on micro-watersheds to be treated and exploring alternative management strategies. This chapter suggests the need to motivate farmers through capacity building, enhance the commitment of local government actors, and introduce participatory planning to enhance mutual learning and collective decisions.

In chapter 5, the thesis employs a more complex Agent-Based Model to explore the effect of six scenarios (doing business as usual, motivating farmers, establishing and strengthening micro-watershed associations, introducing alternative livelihood opportunities for the poorer farmers, enhancing the commitment of local government actors, and integrating multiple interventions by jointly considering all previous alternative scenarios) on both area of land covered and quality of SWC structures. The empirical data required to develop the model and the scenarios were drawn from chapters 2, 3, and 4. The result of the scenario analysis reveals that integrating multiple interventions has the highest impact in all *Kebeles*, and within this scenario enhancing the commitment of local government actors through capacity building generates most effect, yet requiring low investment. Other scenarios have limited, but differential influence on the outcomes of the program across the *Kebeles*. However, all aforementioned alternative scenarios have some added value compared to doing business as usual. This chapter suggests the need to give much more attention to enhancing the commitment of local government actors through capacity building.

The final chapter of the thesis concludes that the CBWM program has a number of limitations, including a top-down planning approach, low awareness and motivation of farmers to participate in the program, poor commitment of local government actors, too much emphasis on the construction of SWC structures rather than paying attention to rural livelihoods, and poor maintenance of the SWC structures. To enhance the outcomes and sustainability of the program, the thesis suggests the need to implement a participatory integrated watershed management approach in the CBWM program, by focusing on locally sensitive community empowerment schemes.



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Samuel Assefa Heban was born on 19 June 1982 in Arsi Negele District of Oromia Regional State, Ethiopia. He obtained his first degree (BA) in Sociology and Social Anthropology from Addis Ababa University in May 2006. After graduation, he was employed as a project and training officer at Arba Minch Rehabilitation Center - a Non-Governmental Organization. After a year of service, he joined Addis Ababa University to pursue his graduate study and received a second degree (MA) in Sociology in July 2009. After completing his study, he was employed as a lecturer at the department of Sociology, Addis Ababa University.

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Scientific Publications

Assefa, S. 2011**.** Farm households' food insecurity and their coping strategies in Arsi Negele District of Oromia Region, Ethiopia. Ethiopian Journal of the Social Sciences and Humanities, 7 (1-2), 27-54.

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Socio-Economic and Natural Sciences of the Environment

D I P L O M A

for specialised PhD training

The Netherlands research school for the
Socio-Economic and Natural Sciences of the Environment
(SENSE) declares that

Samuel Assefa Heban

born on 19 June 1982 in Arsi Negele, Ethiopia

has successfully fulfilled all requirements of the
educational PhD programme of SENSE.

Wageningen, 3 November 2020

Chair of the SENSE board	The SENSE Director
Prof. dr. Martin Wassen	Prof. Philipp Pattberg

The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)

KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

The SENSE Research School declares that **Samuel Assefa Heban** has successfully fulfilled all requirements of the educational PhD programme of SENSE with a work load of 31.6 EC, including the following activities:

SENSE PhD Courses

- Environmental research in context (2015)
- Basic Statistics (2015)
- Introduction to R for Statistical Analysis (2015)
- Research in context activity: 'Initiating and Organizing Stakeholders Workshops in three *Kebeles* (villages) of Boset District, Ethiopia'(2018)'.

Other PhD and Advanced MSc Courses

- Agent-based modelling of complex adaptive systems, Wageningen University (2016)
- The Art of modelling, PE&RC and WIMEK graduate schools (2019)

Management and Didactic Skills Training

- Supervising 6 BA students with thesis (2017-2018)
- Teaching in the BA course 'Environment Sociology' (2017-2018)
- Teaching in the BA course 'Social Policy and Planning' (2017-2018)

Oral Presentations

- *Evolution of watershed management approaches and Practices in Ethiopia.* MIH symposium, 16 January 2018, Addis Ababa , Ethiopia.
- *Assessing outcomes of the campaign-based watershed management program in Boset district*, Ethiopia. Workshop on "Challenges and opportunities of environmental protection in Boset District", 6 March 2018, Bofa town, Ethiopia.

SENSE coordinator PhD education

Dr. ir. Peter Vermeulen

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