Farmers, Institutions and Land Conservation

Institutional Economic Analysis of Bench Terraces
in The Highlands of Rwanda

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For Justine & David, Divine, Joshua

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This thesis is part of the great achievements of my life. It draws from a vision crafted since 1998. At the time, I was still doing my BSc in Economics at the National University of Rwanda (NUR); I needed to get a distinction grade in order to qualify to apply for an Assistant Lecturer position at NUR, which, in turn, would allow me to pursue further studies. At the time (and currently), it was well known that those pursuing an academic carrier were likely to get more opportunities for scholarships than those in other professional areas.

My first employer was World Vision International (WVI), in particular its development activity programme (DAP) funded by USAID for a period of two working years (November 2000–November 2002). My major job description involved the planning and the distribution of food for work for payment of those involved in bench terrace construction. During this period, the first research insight was 'farmers receive rewards that are not proportional to their efforts and time in terracing'.

I joined the NUR as an Assistant Lecturer in the Department of Economics in November 2002. In 2004, I enrolled in the Masters Programme of the Agricultural Economics Department of the University of KwaZulu-Natal, South Africa. My research topic aimed at analysing the impact of farmer support and socio-economic factors on agricultural production in the Gikongoro province, Rwanda. After my Masters in South Africa, I was transferred from the Department of Economics to the Faculty of Agriculture where I was commissioned to head a new Department of Agricultural Economics and Agribusiness, created in 2006.

This thesis contributes to the same research insight as indicated above although in a wider sense. The current stage contributes to the above vision. It results from a long journey started when I was taken to primary school without knowing that it would be a long *Safari*.

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My life is to thank you Lord in All.

Alfred R. Bizoza

8th June 2011

CHAPTER 1

SETTING THE STAGE

1.1 Introduction

Land degradation is widely recognized as a problem for agricultural and rural development in many developing countries (Blanco and Lal, 2010; Lal, 2001; Pretty and Shah, 1997; Anderson and Thampapillai, 1990; Anderson, 1984). Because of its adverse agronomic, environmental, social and economic effects, it has attracted considerable attention from scientists and development agencies around the world (Amsalu, 2006).

Land degradation as a result of soil erosion in Rwanda is well documented as a factor hampering agricultural development and land-based livelihoods. The agricultural sector constitutes an important part of the Rwandan economy and contributes greatly to the country's overall economic growth. In 2008, the agricultural sector has contributed as much as 11.2 per cent to the national economic growth rate (MINECOFIN, 2009). The sector also provides a means of living for about 80 per cent of the total population.

Many parts of the country are mountainous with steep slopes, which allows for easy soil run-off and, hence, contributes to soil erosion. It decreases the productive capacity of the land to support food demands of a population of more than nine millions inhabitants, which growths at a rate of about 2.6 per cent per annum (MINECOFIN, 2007). At the same time, the per capita size of fields in Rwanda has diminished dramatically in the last 3 decades (Bidogeza *et al.,* 2009). In order to increase agricultural production, farmers can no longer expand their fields by opening up virgin lands in area that have not yet been settled or cultivated (Clay and Reardon, 1996). Rwanda is characterized by small and fragmented farm holdings, declined soil fertility and increased soil acidity (Clay *et al.,* 1998; Olson, 1994). In such situations and conditions, soil erosion aggravates the problem of food security, poverty and, eventually, other issues of quality of life. All this underlines the need to conserve soils and water in Rwanda.

Experts have addressed the erosion question by arguing for the implementation of soil and water conservation programmes. Soil and water conservation (SWC) stands for any set of measures aimed at preventing or at least reducing the effects of soil erosion, water loss and run-off, to maintain the quality of soils and possibly to increase crop production (Posthumus and Stroosnijder, 2010; Morgan, 1986; Stocking *et al.,* 1993). SWC measures range from 'biological', also known as 'vegetative', methods to 'physical' or mechanical methods, such as terraces (Hurni *et al.,* 2008; Graaff, 1996). From pre-colonial times to the present, Rwanda has seen many organized attempts to implement SWC measures. Over the last 120 years, a variety of technologies and infrastructural devices have been put in place to reduce soil and water erosion. Bench and progressive terraces are part of the SWC techniques implemented by farmers in many parts of Rwanda over time, with or without support from government or from non-government organizations. However, many parts of the country still suffer from soil erosion. The 2008 National Agricultural Survey (NAS) estimates that about 40 per cent of the potential cultivable area needs to be protected with anti-erosive measures. Our own observations indicate significant variation in the extent to which SWC infrastructure has been put in place and used. Some farmers have not adopted bench terraces to protect the soils and others have done so marginally or do not use them. Rwanda is no exception. Research in other tropical countries acknowledges that SWC measures are not always adopted (World Bank, 2006). This phenomenon raises questions about the way in which SWC has been implemented in Rwanda and about the choices that have been made past and present about which technologies and infrastructure to build. A critical analysis of SWC measures and policies will increase our understanding of why terraces are not used or only in part. We find this particularly important for contexts like Rwanda, which are characterized by high population density and scarce land resources.

This thesis is constructed around a number of articles about soil and water conservation issues in Rwanda. Together, these articles explore the historical and contemporary dimensions of SWC interventions. We focus on bench terraces as these later have become predominant, for reasons that will be explained. The following part of the chapter provides an overview of some of the main theoretical perspectives and development approaches that have guided land degradation and conservation debates. A concise theoretical overview is useful for identifying the kind of questions that one needs to ask to understand the complexities of soil and water issues and phenomena in Rwanda. The chapter continues by formulating objectives and research questions, a short description of the research area and the data collection procedures.

1.2 Theoretical perspective

This section provides an overview of the three main theoretical perspectives on development approaches to land degradation and conservation in developing countries. The intention here is mainly to highlight the core assumption(s) of the causes (natural or human induced) and effects, and the questions that were raised to unpack land degradation and conservation, and how the various theoretical perspectives have inspired development approaches designed to deal with the problem.

Three major theoretical perspectives on soil erosion in developing countries can be distinguished (Ananda and Herath, 2003). A *first* school of thought explains land degradation in a Malthusian way with reference to population increase and poverty (Amsalu 2006; World Bank, 2006; Hetermick 2007; Stephenson *et al.*, 2010). The assumption is that population growth causes mounting pressure on the land, leading farmers to cultivate marginal and often fragile and steep lands. The people most affected are resource-poor farmers who depend heavily on these lands for their livelihoods and who are unable to invest in SWC measures to maintain land quality (Blanco and Lal, 2010; Lal, 2009). The *second* strand explains erosion problems and phenomena through the nature of state policies. Price support, subsidized credits and soil conservation subsidies are not seen as conducive incentives for farmers to invest in land quality. The theory holds that incentives and subsidies from government and other development agencies distort the real sense of soil conservation and, hence, intensify soil erosion (Ananda and Hearth, 2003; Bunch, 1999). A *third* perspective associates land degradation with weak institutions. Developing countries with high erosion risks have often weak institutions, such as substandard property rights and high transactions costs. These institutions fail to secure property rights, promote markets, policies, and other regulations that are conducive to soil conservation (Kirsten *et al.*, 2009, Agrawal, 2001; Shiferaw and Holden, 1999; Barbier, 1997).

As a whole, the above three schools of thought underscore the importance of factors and processes such as population increase, poverty, inappropriate incentives and subsidies, and weak institutions. This brings us to the *second* orientation of the literature:

measures and approaches to address land degradation. These approaches have been grouped and classified as classical, populist, and neo-liberal development approaches to land degradation (Biot *et al.*, 1995; Blaikie, 2000). Although these approaches have their own specific sets of assumptions, they overlap in the sense that they do not associate in a linear way with one of the three theoretical perspectives outlined above. These approaches are theoretically eclectic and are differentiated primarily from one another by their conception of the role of the state to combating land degradation and of the developmental role assigned to farmers, their organisations and the views of experts and policy-makers (Biot *et al.,* 1995:3-6).

Classical development approaches

The classical approaches depart from the assumption that 'the extent of and solutions to the problem of land degradation are well known, but the problem is to get people to implement them' (Biot *et al.,* 1995:3). This development approach argues for a role of the state with top-down and coercive measures, focused on technology transfer, and often informed by state-sponsored scientific institutions (Blaikie, 2000). It assigns to the state a crucial role in driving rural development and land management in particular. The state is viewed, therefore, as an 'engineer' with a designed development master plan that needs people to implement it. However, the question is what motivations the state has to intervene in land conservation?

Long-term SWC measures, such as bench terraces, require investments that, in many cases, go beyond a farmer's capacity (e.g. Hurni *et al.*, 2008). Few farmers implement these measures without external support from GOs and NGOs (Spiteri and Nepal, 2006; Winters *et al.*, 2004; Bunch, 1999). On the other hand, soil conservation entails not only on-site (private) but also off-site (public) benefits, which explains why both private and public parties have an interest in land conservation. Consequently, different measures from state policies and regulations to direct incentives are used to induce adoption of soil conservation measures. However, emphasis is put on how to mobilize labour for the collective construction of soil conservation structures. Interventions under such classical or top-down development models are trapped in weak assumption(s) that labour is the major constraining factor for land conservation. That is, if labour is pooled and SWC structures are established, farmers will continue to use them and enjoy benefits from these SWC measures. Unfortunately, this is often not the case (Hudson, 1991).

In many parts of Asia and Africa, land conservation followed these top-down approaches to induce adoption of SWC measures, mostly of bench or stone terraces (e.g. Java, Indonesia, Jamaica, Nepal, Ethiopia, Kenya, Rwanda) (Barbier, 1990; Gebremedhin and Swinton, 2003; de Graaff, 1996). Later, some of these techniques were abandoned, others were destroyed by farmers, because farmers' priorities and abilities to use and maintain such technologies were insufficiently considered by SWC projects in the design and implementation (Amsalu, 2006; Mafuka *et al.*, 2005; Graaff, 1996). Rwanda did not escape this era of soil conservation; we will describe this later in this thesis while discussing the role of the state in soil erosion control under different political regimes (Chapter 2).

Populists and development

Populists are guided by the hypothesis that 'the nature and extent of land degradation are imperfectly understood, that local people reject conservation technologies for good reasons and, in fact, adopt their own individual and collective approaches that have in the past resulted in sustainable livelihood practices' (Biot *et al.*, 1995:5). They advocate an anti-state position, and seek ways to promote people-centered, bottom-up and participatory approaches to land conservation. They support the view that decisions about land conservation should be based on farmers' knowledge and farmers' priorities. The change in this direction was driven by the recognition that farmer's needs and their capabilities to adopt new technologies were diagnosed insignificantly by the classical approaches (Blaikie, 2000). Due to the need to embrace farmers' skills in development activities, including natural resource management, new institutions had to be designed or existing ones had to be enforced through policy (see also Pant, 2000; Webb 2001; Brown, 2003). Both notions of participation in and institutional innovation of soil conservation cluster around common-pool resources, since many decisions about their management require collaboration and, hence, participation in the process of decision-making itself (Biot *et al.*, 1995). Case-studies that dwell on people's views about their participation in decision-making processes during the design and the implementation of SWC measures are scanty and limited.

Over the years, and especially in the 1990s, farmers in Rwanda were encouraged to create different forms of organizations (such as associations and co-operatives) to improve their roles or to participate in rural development activities. Hence, the role of these organizations is perceived vital in policy, especially in SWC measures to counter soil erosion, such as terraces. There is a need to know how these farmers' organizations operate vis-à-vis their members and policy or project interventions. How famers experience their participation in SWC interventions and how they perceive the role of their organizations increase the understanding of soil and water conservation issues in Rwanda.

Neo-liberalists

Similar to the populists, the *neo-liberalists* argue against a direct role of the state in land conservation. They maintain that 'suitable technologies presently exist and can readily come into existence; the problem is to understand the present structure of incentives that prevents land users from adoption of them , and to design incentives that will induce adoption' (Biot *et al.*, 1995:6). Clearly, the structure of incentives and institutional arrangements required to induce adoption of SWC measures is at the centre of their argument (Biot *et al.*, 1995, Spiteri and Nepal, 2006). Moreover, they also recommend an analysis of other factors affecting the adoption (or not) of soil conservation practices.

Investing in soil conservation practices such as terraces demands strong decisions from farmers. Being economic optimizers, they will adopt new SWC measures if they expect better economic rewards from doing so (Barbier, 1990; Hudson,1991; Lutz *et al.*, 1994). Unfortunately, this 'farmer rationality' is overlooked by some policy or project interventions. This may explain partly why some farmers do not adopt and possibly abandon established SWC measures after GO and NGO interventions (Neil and Lee, 2001). Nevertheless, in situations where farmers have to choose whether to adopt (or not) new conservation techniques, direct economic incentives such as increased production and economic returns expected from land conservation appear the main incentives to adopt (Spiteri and Nepal, 2006; Shiferaw and Holden, 1998; Anderson and Thampallai, 1990). But long-term conservation techniques such as terraces take a long time to be both financially and technically effective. A study by Posthumus and Stroosnijder (2010) in the Peruvian Andes shows that bench terraces did not result in any short-term change in soil properties – fertility or infiltration capacity. Accordingly, in such situations, the net returns without soil conservation will potentially exceed those with conservation in the early stages until the gap declines to eventual higher net returns with conservation (World Bank, 2006). Thus, lower returns at farm level may explain why certain farmers are risk averse to uptake more SWC measures (Tefera and Sterk, 2010).

It is little known whether or not established bench terraces are cost-effective at farm level in Rwanda. Cost-Benefit Analysis (CBA) is usually used to test under which conditions bench terraces are profitable (e.g. Posthumus, 2005; Pearce, 1998). In this thesis, financial CBA is applied at plot level to analyse under which socio-economic conditions bench terraces are profitable in Rwanda. Since financial incentives are not the only factors explaining adoption process of terraces, further analysis is required.

In a context of extensive policy and project intervention in soil conservation, which occurs in many developing countries, adoption of conservation technology takes place within various and confounding situations. Some farmers adopt conservation measures due to coercive and/or direct material incentives (Speteri and Nepal, 2006; Pretty and Shah, 1997, de Graaff, 1996), while others adopt to comply with political and project goals (Blustain, 1985). In addition, adoption may occur as a result of collective decisions due to downstream and upstream effects, such as in watershed development approach; or simply as a result of increased farmer's awareness of the costs and benefits of technology adoption. The latter is exception rather than rule in many developing countries (Blustain, 1985; Hudson, 1991).

We will specify different econometric models based on previous studies of technology adoption to identify which factors explain current and future adoption of terraces in the highlands of Rwanda (Knowler and Bradshaw, 2007; de Graaff *et al.,* 2008, Rezvanfar *et al.,* 2009). We will consider the role of various local institutions (such as tenure security and social capital) and farmers' capacities to invest in existing or new terraces.

1.3 The research focus

Following on from the above debate, we will develop relations between the perspectives and approaches on land degradation and conservation. The populist, classical and neo-liberalist approaches have in common that the solutions for the soil erosion problem are assumed to be well known. The technologies are there but not well implemented, well built or well embedded in proper policies. This is in contrast to the populist position, which supports reliance on indigenous knowledge and that failure to adoption is due to unsuitable government policies. The major difference between the three approaches is their perceived role of the state. The classical position is guided by the first perspective that population pressure on land and poverty are the major problem, calling for top-down implementation by the state. The neo-liberalists follow the perspective that inappropriate incentives are conducive to soil erosion. It poses that the state should not be involved directly in land conservation but rather that it should design incentives and institutions that are conducive to soil conservation. Though critiqued, the populist approach has become popular for many development agencies, especially in soil and water conservation (Biot *et al.,* 1995). In all, the role of the sate, farmer participation, incentives, and institutions are major cross-cutting issues in all perspectives and approaches to land degradation and conservation.

Successful shifts in the above policy and development paradigms in land conservation remain unclear in many developing countries such as Rwanda. The perspective guiding this study departs from the above debate on the classical, populist and neo-liberal development approaches. We will consider the role of the state and development agencies, farmer participation and the role of farmers' organizations, incentives, and local-level institutions to be important 'objects' or 'subjects' to understand soil and water conservation issues in Rwanda.

Most farmers in Rwanda are resource scarce, making it difficult to invest in soil conservation practices (Clay *et al*., 2002). This provides ample reason for the government and NGOs to intervene in soil conservation practices. For this purpose, various incentives are used and new policies are designed to encourage farmers to adopt soil conservation practices. We have opted for a historical perspective to supply accounts of SWC measures used over time and of the role of the state in the environmental discourse in Rwanda (Chapter 2). Farmers are encouraged to participate collectively in soil erosion control through their organizations and other local-level institutions. At the same time, the government designs and implements other development policies, including land conservation. This makes it difficult to dissociate the roles of the state and of farmers and their organizations in land conservation. In Chapter 3, we will opt for a socio-technical and institutional analysis of bench terraces to asses farmer participation and how the state–farmer relationships affect strategies for soil and water conservation in Rwanda. Different SWC measures such bench and progressive terraces have been implemented in Rwanda. However, there is limited research to show whether these are cost-effective from a farmer's perspective (see Chapter 4). Likewise, as indicated in Section (1.1), some farmers have adopted terraces and others have not. There is little knowledge of factors affecting farmers to adopt (or not) SWC measures proposed by policy and projects in the Rwandan case. In Chapters 5 and 6, we have opted for an econometric approach to identify which factors affect adoption of bench and progressive terraces in Rwanda.

Despite substantial contributions of earlier work on technology adoption, studies that analyse the adoption of bench terraces in the historical context of state–farmer relationships and social and institutional arrangements are scarce. The thesis is, therefore, innovative in its interdisciplinary approach to bring new understanding of the issues emerging during the design, implementation, and continued use of SWC measures in developing countries. This is the first attempt to analyse the adoption of bench terraces from an institutional and socio-economic perspective in Rwanda.

1.4 Objectives and Research questions

This study attempts to increase the understanding of the complexity of the soil erosion problem and of how farmers and institutions affect the adoption and effectiveness of soil and water conservation measures in Rwanda. More specifically, the study aims to:

1. Provide a historical account of SWC measures used and the processes of their implementation from the pre-colonial era to the independent state in Rwanda.
2. Assess how farmers participate in soil conservation and how state–farmer relationships affect SWC strategies in Northern and Southern Rwanda.
3. Investigate under which socio-economic conditions bench terraces are financially viable in the Northern and Southern Rwanda.
4. Explore which factors explain the current and future adoption of terraces, with close attention to the potential effects of local institutions and farmers' capacity to invest in bench terraces in the Northern and Southern Rwanda.

In order to address the main issues raised in Section 1.1, the following research questions were formulated based on the specific objectives mentioned above:

1. What soil erosion control measures have been used in Rwanda from the pre-colonial regime to the post-independence state?

2. How do farmers participate in soil conservation and how do state–farmer relationships affect soil conservation strategies in Northern and Southern Rwanda?
3. Do farmers with bench terraces receive higher investment returns from cultivating plots compared to those with slowly forming terraces or plots with no terraces at all?
4. Which factors explain current and future adoption of terraces in Northern and Southern Rwanda?

1.5 Research area and data collection procedure

Rwanda is a developing country located in the central and eastern part of Africa. It is landlocked between Uganda, Tanzania, Burundi and the Democratic Republic of Congo (DRC). It is a mountainous country (1500 m absl), which is why it is nicknamed a 'country of thousand hills'. Since 2006, Rwanda is divided into four provinces plus the capital city Kigali: Northern, Eastern, Western, and Southern provinces. The provinces are subdivided into 30 Districts, which, in turn, subdivide into 416 sectors – a sector is an administrative unit above a village and constitutes the third administrative unit from the bottom under the District management.

The research was carried out specifically in the Northern and Southern provinces of Rwanda. These two areas are prone to soil erosion and have received great attention from projects and policies of soil erosion control using both bench and progressive terraces. The choice of the research sites and respondents was carried out using a multistratified random sampling procedure. Geophysical criteria such as altitude and slope steepness are the main criteria used. These are well documented in the literature as necessary conditions to establishing physical structures such as bench and progressive terraces.

During slope mapping, two agro-ecological zones with somewhat similar physical conditions (mainly land slope) were selected in *phase one*: Crete Congo–Nile Watershed Zone (CNWZ), which covers major part of Nyamagabe District (South); and Buberuka High Land zone (BHLZ), covering the main part of Gicumbi District (North).

In *phase two*, the two agro-ecological zones were classified into three main areas based on percentage occurrence of three slope categories: 12–25%, 25–55%, and 55–70%. Areas containing the two first slope categories were maintained and those in the third category were rejected as they are meant for conserving techniques other than bench and progressive terraces (see Appendix 1.1). Within the two slope categories maintained, randomly selected areas covered 20 sector administrative units.

In *phase three*, we selected randomly one small-scale farmers' association/co-operative from each sector containing 20 associations, whose members were involved in the focus group discussions carried out during February–March 2009. Information provided during these discussions is analysed mainly in Chapter 3. During these discussions, farmers guided the researcher and his assistants to locate, in their respective sectors villages or sub-catchment areas, where bench (BT) and/or progressive terraces (PT) were dominant and where there were areas with fewer or no terraces at all (NT) (see Appendix 1.2). At this stage, some maps were designed by farmers, from which we took GPS points (X(m) and Y(m), altitude (m)) to map the research area, using Geographic Information System (GIS) in *phase four* (see Appendix 1.3). Of the 20 selected sectors, 10 stand for places were BT are dominant, 6 for PT , and 4 for NT.

Finally, 301 households were randomly selected from villages/sub-catchments maintained in previous stage for an extensive farm survey conducted in April–May 2009.

Out of 301 households, 54.8% (165) are from the North (BHLZ) and 45.2% (136) are from the South (CNWZ). The heads of these households provided information about their 907 plots, with an average of about 3 plots per household. Data collected during the survey is analysed in Chapters 3 to 6. Table 1 gives a summary of sample estimates per sample province (Northern and Southern).

Table 1. An overview of the sample design

Province	% Slope Category	% Occurrence	Sectors	Sub-catchment	Sample Households	Sample Plots	Mean Altitude
North (BHLZ)	12–25* 25–55**	35–40 60–70	12	75	165	540	2053
South (CNWZ)	12–25 25–55	35–55 45–50	8	34	136	367	2163
Total			20	109	301	907	2103

**: Appropriate for slowly forming terraces and ** for bench terraces*

1.6 Thesis outline

This study consists of seven chapters. Chapter 1 sets the stage of the thesis in terms of problem statement, theoretical perspective, objectives and research questions, the research area and data collection procedure, and ends with this outline. Chapter 2 will provide an account of soil erosion against the background of the environmental discourses that have emerged over time in Rwanda. Chapter 3 will discuss how farmers perceive their participation, the role of their organizations and institutions in soil and water conservation in Northern and Southern Rwanda.

Chapter 4 will focus on the financial profitability and technical effectiveness of established bench terraces in the research area, while Chapters 5 and 6 are concerned with the adoption of bench and progressive terraces in the study area. Thanks to information obtained from farmers during the survey, the impact(s) of various local institutions on the adoption of these terrace structures is estimated in Chapter 5. Chapter 6 will 'unpack' the adoption process of bench terraces to estimate current and future adoption upon farmers' capacity to invest in existing and new terraces. Finally, Chapter 7 will provides some major conclusions and policy and research options for future generation of soil and water conservation in Rwanda. Figure 2 shows the organizational framework of the study of SWC issues in Rwanda.

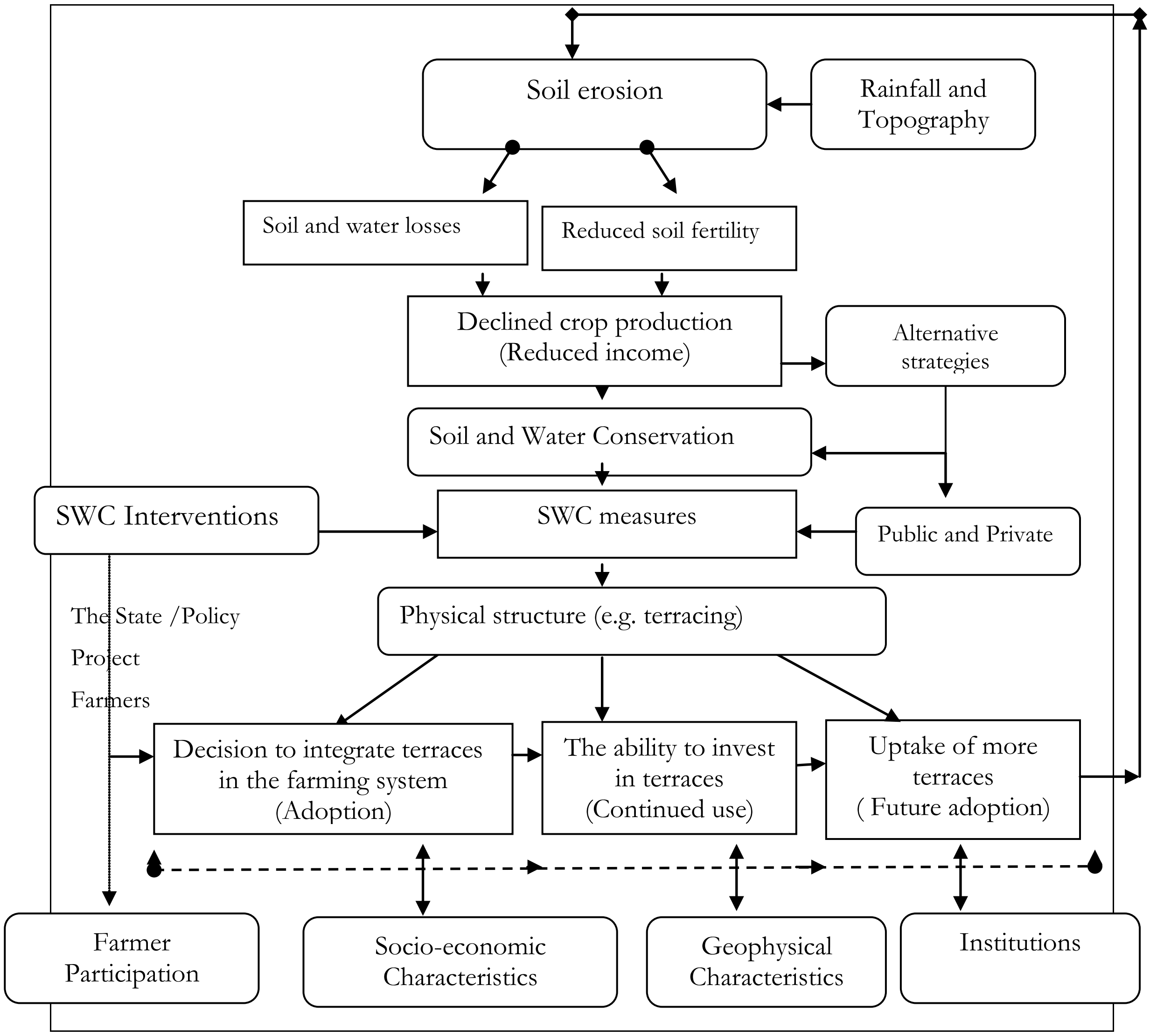

Figure 1: The organizational framework of the study of SWC issues in Rwanda

CHAPTER 2

SOIL EROSION IN RWANDA IN A HISTORICAL PERSPECTIVE[1]

2.1 Introduction: environmental discourses in Africa

The colonial and post-colonial states in Africa have played key initiating and co-ordinating roles in responding to environmental problems (Olson 1994, Bernstein and Woodhouse 2001). In the early part of the twentieth century, colonial states began to take serious cognizance of soil conservation issues (Pretty 1995). A series of environmental measures were implemented to halt soil erosion, particularly in the overcrowded reserves of settler colonies such as Kenya, Zimbabwe and South Africa. Most measures were in the form of sanctions and regulations to prevent the overuse of land by cattle and people. The predominant assumption of the discourse has been for a long time that farmers are poor managers of land, ignorant of soil erosion problems, and not prepared to adopt expert-designed innovations such as terraces. This explains why decades of state implemented soil and water conservation programmes had little or no impact on soil erosion (Pretty and Shah 1997).

Many authors have commented critically on the nature of the state's environmental discourse. Common to the critique is that farmers should not be seen as ignorant but rather as knowledgeable and creative actors (Pretty and Shah 1997). The academic discourse has clearly shifted towards examining institutional factors that explain why farmers do not adopt new technology (e.g. lack of involvement of farmers in the design of innovations, improper incentives such as food for work) (Kirsten *et al.* 2009). There is, however, also some agreement in the literature about Africa and Rwanda, as we will see, that the discourses of the state ignore or marginalize other competing and perhaps robust discourses that have emerged in the past and continue to emerge in the present.

Historical sources, for instance, show that during pre-colonial period and the early years of colonization there was some organised attention to soil conservation in Rwanda, either by cultivators and herders or by the then local authorities. This is in contrast to most environmental historians who argue that the colonial states in Africa have imported ideas of conservation from the United States, when the dust-bowls of the 1930s prompted the government to implement soil erosion programmes (Anderson 1984, Beinart 2003).

This paper presents a literature review examining the Rwandan highlands and their problems of land degradation. It outlines and focuses on the environmental discourses of the colonial and post-colonial state in its endeavour to contain or prevent the degradation of highland resources. Environmental discourses are important as they feed state agrarian policies in Rwanda and elsewhere, and legitimize direct interventions with regard to land use (e.g. preventing and sanctioning certain practices) and the implementation of land tenure policies and the formation of markets (Bernstein and Woodhouse 2001). The measures taken in the realm of soil conservation and the dynamics they evoke can thus not be disconnected from the state and its agrarian

[1] This chapter will be reworked into a journal article

policies. The article also points out the shifts in environmental discourses that have emerged in Rwanda over time.

2.2 Methodology

An analysis of agrarian and land conservation policies and the discourses that underlie these is useful as it discloses how and why certain conservation measures are taken. Discourse analysis deals with 'language-in-use' in written texts (Gasper and Apthorpe 1996), media, and journal articles, as well as in peoples' narratives. There is a temptation in discourse analysis to indulge in philosophy and language studies. The test, as Gasper (1996) argues, lies not in the abstract reasoning but in our ability to provide insights and to convey to others how these can be generated. The study of discourse comes out of a tradition of post-structuralism, which builds on a notion of the world as socially constructed rather than pre-existing reality, and posits that language not only describes reality but also works to create it (Lehrera and Beckerb 2010). With this in mind we define discourse as a set of interconnected statements that provide explanations for processes and problems – in our case for problems of land degradation in mountainous regions such as Rwanda.

The social science literature asserts that there is not one single discourse but rather a variety of often contrasting and competing but also opposing discourses. Some are articulated by the state in the form of policies and others by land users and their organisations as well as by civil society like non-governmental organisations (Leach and Fairhead 2000). The discourses articulated by the state are expressed in policy documents (i.e. texts) that build on and are usually derived from views and insights generated and expressed by experts, academics and politicians. Farmer discourses, on the other hand, are usually but not exclusively uttered in narratives (e.g. 'this is how we farm' or 'how we build our terraces') but also in their farming practices (Van der Ploeg 2003). These narratives are frequently documented and analysed in publications by historians, rural sociologists and development anthropologists studying process of agricultural and rural development (Basset 2003, Van der Ploeg 2003, Netting 1993).

In this article we limit ourselves to an analysis of the discourses conveyed in Rwandan agrarian policy documents, specifically those with regard to soil erosion. A discourse analysis of the content of policy texts usually seeks to expose the theoretical assumptions about the nature of the problem and how (e.g. in what language) these are framed by experts and policy makers (Gasper 1996). Analysis of the content of policy documents will also show the kind of resources that are required to deal with the identified problems and how to deploy them Policy discourses tend to phrased in terms that seem to be politically neutral, such as 'land' or 'mountain' (Borras and Franco 2009). Keely and Scoones 2003) point out that the framing of problems is derived from a distinct body of knowledge. Pain (1996) and Scott (2009) for instance emphasize that it has become common in regional policy documents in Bhutan that 'mountainous' often stands for 'remote' and 'isolated'. Mountainous in most Rwandese policy documents is imaged and problematized as erosion sensitive areas which need protection. The solution for such problems are predominantly phrased in terms of building terraces to prevent run-off and loss of top soil. Leach and Fairhead (2000) refer in this context to policy discourses as 'received wisdom', which contain assumptions about reality that are not tested in the conditions they apply (see also Leach and Mearns 1996). Environmental policy-making in this view is plagued by the hegemony of certain orthodoxies, taking for granted certain narratives about resource degradation and its underlying processes. As we will see, constructing bench terraces have for long been seen as the best way technology to halt erosion, often ignoring other experiences with the battle against erosion. These orthodoxies lead not only to erroneous interpretations of environmental and socio-economic change in Africa but also to 'bad' policy choices (Keeley and Scoones 2003).

This paper is limited to a content analysis of policy documents that are relevant for agricultural development occurring in mountainous environments. We collected recent policy documents related to more broadly to agricultural development (Republic of Rwanda 2009, Rwanda Agricultural Development Authority 2005) as well as report on how soil erosion is identified and solutions discussed (Van Den Steen 1965, Republic of Rwanda 1982, Fleskens 2007). We also consulted scientific documents that assisted us in understanding how the erosion policy discourse has emerged over time and whether continuities exist at the level of discourse Investigating continuities and discontinuities is useful for an analysis of changes over time, not as a simple, unbroken line of events, but as a set of institutional and discursive linkages. The continuities that we explore here relate to the basic foundations of agrarian and environmental policies.

The account of how farmers deal with and respond to erosion problems and how they interact with the expert system and the state is beyond the scope of this article and is subject to on-going research.

2.3 Agrarian policy in Rwanda

Rwanda has a favourable altitude, climate and rainfall regime for agriculture, in addition to fertile soils in some zones, though in many areas they are frequently high in acidity. The hilly topography, with many steep slopes, has been conducive to depleting soils through rapid runoff of surface water and soil erosion. More than half of Rwanda's territory is identified as highlands. The discourse about African highlands and mountainous areas commonly view these areas not just as important in relation to climate and conservation (Lewis and Berry 1998). The eastern and central African highlands are particularly important because they support a large number of rural people in their attempts to construct livelihoods (Assmo and Eriksson, 1994). These areas are densely populated and receive substantial rainfall, which enables a productive, land- and labour-intensive agriculture. However, due to their steepness and physical characteristics the highlands are environmentally fragile and prone to erosion (Lewis and Berry 1998).

The Rwanda Development Agricultural Authority (2005) estimates that 77% of Rwanda is threatened by soil erosion: 38% of the land has to be safeguarded from erosion, and 39% is considered to be at high risk. These figures underline the importance of a range of anti-erosion measures implemented by the colonial and post-colonial states over the past 100 years. A key dimension of Rwanda's agrarian policy (see for instance Republic of Rwanda 2009), which also applies more broadly in central Africa, is the desire both to transform (highland) environments from open common property resources to closed common property (e.g. individual freehold property; Scott 2009) and to foster the commoditization of its social and natural resources (Bernstein and Woodhouse 2001). Highland and mountain resources (e.g. land, crops and cattle) will increasingly change from assets that are exchanged locally to commodities which will firmly integrate peoples' livelihoods into global economic development. Bench terracing and land tenure reform have become the predominant socio-technical expressions of the state's land conservation policy discourse in Rwanda (Republic of Rwanda 2009; Rurangwa 2002).

2.4 Soil conservation in Rwanda

Initiatives to prevent land degradation date back to the early twentieth century, when planting trees and constructing trench ditches were already being promoted to prevent erosion. In both pre-independent Rwanda and Burundi, 750,000 ha of land were planted with trees (Olson 1994). Today, the state encourages the construction of terraces to control soil erosion and reduce the loss of valuable top-soil (Republic of Rwanda 2009, Bizoza and Graaff 2010).

Soil conservation during the pre-colonial era

Before Rwanda was colonised, it was ruled by a monarch. The King was the supreme political authority, assisted by a number of chiefs who were assigned specific tasks. There was a chief in charge of pasture (*umwami w'umukenke*), a chief for land issues *(umwami w'ubutaka*), and a chief heading the army (*umwami w'ingabo*). The monarch had absolute powers. With support from the chiefs, the King could demand the labour of commoners for general purposes such as building and maintaining infrastructure (Rurangwa, 2002).

Soil erosion was not yet identified as a critical issue; access to and occupation of land was a major concern for commoners in Rwanda since the King and elites had overall control over the land and cattle (Newbury 2001). Most of the land was used for livestock production, with only a small portion of land set aside for cultivation. The predominant pattern was to cultivate a field nearest to the homestead, where cattle were kept during the night for safe-keeping. This system allowed the intensive use of manure and compost from household residues (Olson 1994; Newbury 2001). Conserving natural resources was an integral aspect of land use and consisted of *inyanamo* (strip-cropping) and raising *rudumburi* (stone rows) (Nyamulinda 1989). In strip-cropping, fallow spaces were kept between cultivated areas. The stone rows were meant to protect the land from run-off. The scale of these soil protecting practices was rather limited. Since the predominant land-use system hinged on livestock and pasture management, soil problems did not attract the attention of the Monarch. In turn, it may also explain why these soil and water conservation techniques were not recognized, nor was experience with these practices well documented by administrators and travellers. The practices were ignored and, hence, disappeared, gradually to be replaced by new structures (Verwimp 1991).

Erosion control during the colonial era

The German and, later, Belgian colonial administrations introduced a more intensive and sedentary use of land in Rwanda (Olson 1994; Van Den Steen 1965). Soil erosion control was initiated on a modest scale from 1937 onwards. The *Mission anti-erosive* was established in 1945, mandated to better disseminate existing soil erosion techniques. Due to the 1943–1944 famine and World War II, the colonial administration imposed a 10-year development plan (1951–1961) to address food scarcity by stimulating the expansion of the production of cassava, sweet potatoes and coffee as the main cash crops in Rwanda. In 1958, the state introduced and enforced a range of conservation techniques and regulations to prevent erosion (Van Den Steen 1965). These included the construction of hedgerows, leaving spaces between farms for the movement of livestock, and the digging of trenches alongside hedgerows. Burning of fields was forbidden and enforced through penalties and imprisonment. Tree planting, especially with exogenous species was stimulated (Olson 1994). Some of these measures were refuted by farmers due to intangible benefits and non-involvement during the introduction of the measures (Nsengiyunva 1993), or due to other side-effects. Indeed, the open spaces between farms potentially increased soil erosion as a result of intense cattle grazing. Digging trenches or ditches required a lot of labour for both construction and maintenance. The planting of trees was enforced through collective labour (*umuganda*) and did not provide answers to the real problem of decreasing agricultural production. Trees did not protect the vegetative cover downstream and improve soil fertility but supplied fuel, feed and fodder, and poles for construction (Republic of Rwanda 1982).

Soil erosion 1962- 1994

Rwanda gained independence in 1962. The change of government did not imply a new style of governance with regard to the development of mountainous areas and the control of soil erosion. On the contrary, the conservation techniques that had been introduced by the colonial state were maintained by the newly independent regime (Verwimp 1991). Only hedgerows (for mulching and as fodder for livestock) and bench terraces were new additions. The approach remained largely driven by enforcing farmers to adopt new techniques (Kayijamahe 1982). The immediate post-1962 period, however, saw trenches being abandoned and destroyed, which was perhaps an expression of newly regained freedom. Consensus exists over the top-down approach leading to techniques that were generally not trusted by farmers and local technicians (Ndindabahizi and Ngwabije 1991; Guichaoua 1989; Kayijamahe 1982).

In the 1980s, soil erosion control was expressed actively in political terms. The former president Habyarimana labelled 1982 as 'the year of soil erosion control'. The budget for soil erosion control was increased by 40%. In the same year, a seminar convened by agronomists, development practitioners and researchers explored appropriate soil conservation scenarios. Despite all efforts, the 1988 National Commission indicated that 63% of the land was not protected by any of the available erosion control techniques (Ndindabahizi and Ngwabije 1991).

After 1994

The period 1990–1994 was a turbulent one. Up until the 1994 genocide, intense land conflicts forced people to migrate. To a certain extent, these internal migrations and displacements resulted in changes in land use and land cover through deforestation. People who left Rwanda due to the war and genocide then returned and reclaimed ownership of their lands, in successive phases from 1994–1996 (Musahara and Huggins 2005). In 1997, the government encouraged people to share available land resources and it adopted a new policy (*imidugudu*) enforcing settlement in rural villages (Havugimana 2009:24). Some state land (e.g. national parks) was allocated to settle new returnees.

In the post-1994 period, the focus shifted to bench terraces; conservation objectives became closely linked to attaining food self-sufficiency and exporting cash crops. It represented a policy shift away from 'food for work', 'cash for work' or subsidies to lower input costs. The popular political slogan in the previous regime 'work more and hard' implied a development scenario geared towards the intensification of labour (Clay et al. 1998). Together with increased pressure on land due to population growth, this may have accelerated land degradation and soil erosion (Moeyersons 1989).

The emphasis on bench-terrace policies as an effective way to combat soil erosion and to maintain water and soil nutrients is supported by experts (Fleskens 2007). If well maintained they can also improve land management and increase crop yields (Kriegl and Preissler 1987). However, terracing on its own does not ensure increased production. It requires additional investments in inputs such as fertilizers, which farmers often find difficult to secure. Farmers also complain about the high labour input that is required to build and maintain the terraces (Bizoza and Graaff 2010, Fleskens 2007).

At present, farmers are encouraged to combine both mechanical and biological measures: terracing, contour bunds, trenches, and water retention systems at field level, fallows (although limited), hedgerows, intercropping, mulching and tree planting. Additions to the array of conservation techniques include hedgerows planted with agroforestry species (e.g. *Pennisetum purpureum*), which are highly appreciated because they protect the soil and provide fodder for livestock. Zero grazing is being promoted because of its combined effects such as soil protection and integrated nutrient management through manuring, thus strengthening the (re)integration of cultivation and livestock production. Alongside these measures, farmers still have their own ways of protecting crops from run-off (Republic of Rwanda 1982). Unfortunately, these are hardly documented in the literature (Critchley *et al.* 1994).

2.5 Current challenges

The current environmental policy discourse in Rwanda hinges on addressing population pressure and privatizing land tenure (Republic of Rwanda 2009: 10). Land being a fixed asset at a time of population growth poses a serious challenge. A fivefold population increase between 1948 and 2002 (see Figure 1) has led to a chronic and continuous disequilibrium between population density and land size, jeopardizing rural people's abilities to construct land-based livelihoods. In addition, field size decreased as landownership became more fragmented as a result of inheritance. 70% of farms are about one hectare or less and population density is about 376 inhabitants per km^2 (NWRMP 2005). Figure 2 shows land use in Rwanda for recent years. Unfortunately, data that show the shifts in land use over the years is not readily available but there are indications of deforestation and increased cultivation. May (1995), Clay (1996) and Clay and Reardon (1996) argue that the shifts in land use driven by population pressure certainly limits the options to intensify land use continuously. Likewise, Lewis (1992) and Lewis and Nyamulinda (1996) point towards the greater likelihood of severe land degradation and reduced agricultural production. Deforestation, cultivation of bottom-lands and fragile marginal land on steep slopes previously farmed as pastureland, and woodlots have had a negative impact on productivity.

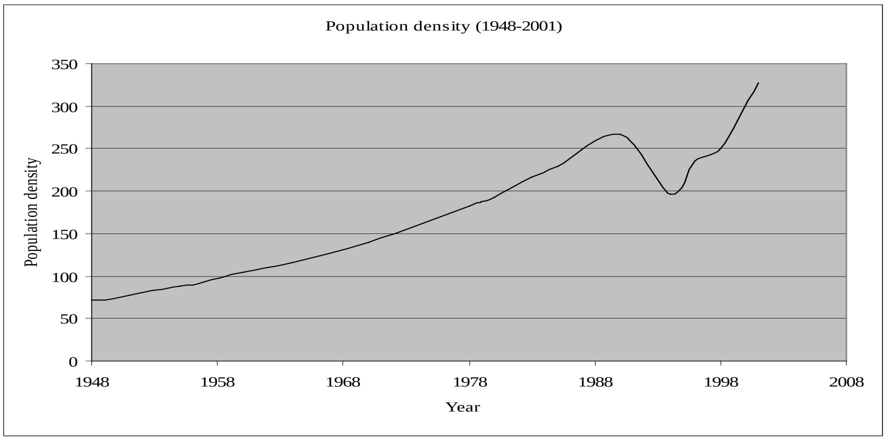

Figure 1: Trend of population density 1948–2008

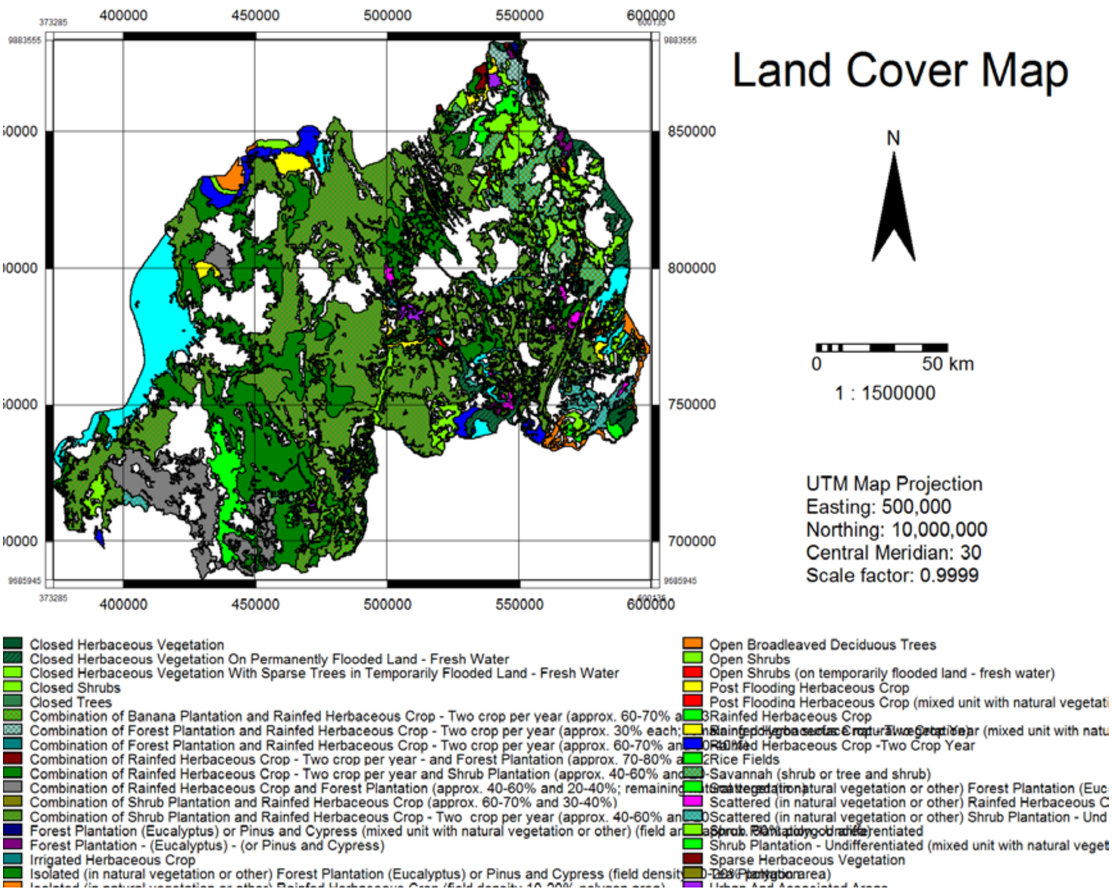

Figure 2: land Cover mapp generated based on Data from Ministry of Agriculture in Rwanda

Land tenure and security of tenure are considered to be key institutional dimensions. Indeed, land rights became a critical factor in the mid-1950s when farmers began to migrate in search of land (Clay and Lewis 1990). The wars of the 1990s led to the forced displacement of farmers, and their gradual return has added to an environmental question of great political sensitivity: all Rwandese people have the right to access land (Musahara and Huggins 2005) but this results in increased pressure on the land.

Land tenure and rights are part of a heated debate because of their strong links with land use. Policy documents state that for soil erosion control and water conservation to be successful, land relations need to be privatized. The assumed linear relationship between land investment and security of tenure is ambiguous, however. This is partly because of the coexistence and overlap of different legal systems in Rwanda. Until recently, the state has claimed ownership of the land with only usufruct rights for users (Musahara and Huggins 2005).The current law, adopted in 2005, moves away from usufruct rights and aims to register and commoditize land. Private land rights are considered an appropriate vehicle for a land market and land investments, and thus for constructing and maintaining terraces.

However, customary land rights are still predominant in Rwanda. Inheritance rather than the land market shapes the transfer of land from generation to generation and from one person to another, effectively creating an informal land market. Farmers believe strongly that the land belongs to them despite the progressive nature of formal titling. Most farmers keep an *ibuku* (book) that contains measurements of their land. Farmers largely rely on their own land and have little opportunity for renting land elsewhere (Clay 1996). In situations where land markets are absent, informal contracts appear to be the best strategy for accessing land. However, this may lead to situations where farmers are reluctant to invest in land or build terraces on rented fields (Clay and Reardon 1996). Informal land access arrangements are also likely to affect farmers applying for loans and credit.

Current land laws in Rwanda thus do not necessarily create security of tenure but of ownership instead. In their study of Ghana, Kenya and Rwanda, Place and Hazell (1993) found that land rights were not a significant factor in determining investments in land improvement. Clay and Reardon (1996:9) argue that 'the stability of tenure, rather than ownership, is the more important factor shaping a farmer's decision to invest in soil productivity and adopt sustainable land-use practices'. Security of tenure allows farmers to maintain and invest more in their land and to obtain long-term land-use rights (Clay 1996). The current legal situation in Rwanda is therefore not conducive to the soil erosion control declared as an important governmental goal (Musahara and Huggins 2005).

2.6 Conclusions

This paper has provided evidence that both political authorities and farmers were cognizant of soil erosion during the pre-colonial and early colonial periods in Rwanda. Nevertheless, the colonial and post-colonial states began to import exogenous ideas about soil erosion, notably about the value of bench terraces. The ensuing measures took the form of regulations to prevent the overuse of land, leaving little room for local farmers to participate in and own the process of soil erosion control. The implementation process was generally enforced as a top-down process rather than being participatory, which would have allowed farmer perspectives to be included. Population increase and land tenure were identified by experts and the state as key social factors shaping soil erosion control processes.

Past and current policies have shown a remarkable continuity of ideas. The persistence of continuities indicates the extent to which the transformation of institutional infrastructure in Rwanda has proceeded hardly unchanged in its content. Historical analysis allowed us to underline the continuity of prescriptions and modes of ordering in the past and present. Distinctions between the pre-, colonial and post-colonial belie the existence of important continuities. Past and present policies set out to commoditise Rwanda's highland and mountain resources (e.g. land, labour, crops and cattle) and to integrate peoples' livelihoods more firmly into global economic circuits. Bench terracing and land tenure reform have become the predominant socio-technical vehicle to achieve these aims. While the state discourse increasingly seeks to privatise land as a key to solving erosion problems, farmers, supported by some academic researchers, contest that this is an appropriate institutional solution and continue to prefer their own land tenure arrangement. Moreover, the state's discourse has given more attention to soil erosion control per se than to slowing down population growth vis-à-vis the available land. The latter seems to be a more promising trajectory for most mountainous regions in the world but requires changes at the level of the soil conservation discourse. If farmers, in collaboration with experts, find ways to improve the land (effectively increasing farm size), population pressure may be less problematic. If combined with a diversification of the rural economy, Rwanda may escape a doom scenario of poverty and insurmountable environmental problems.

CHAPTER 3

LOCAL INSTITUTIONS AND SOIL CONSERVATION IN RWANDA[2]

3.1 Introduction

Rwanda has a long history of providing technical and physical support to farmers and their organizations. The reasoning behind this has been that developmental problems such as poverty or soil degradation stem from problems of climate, soil and a lack of knowledge and information. The solutions that have been offered, however, have been mostly technical in nature: terracing, draining swamps, culling cattle, and so on. Farmers have also been encouraged to cooperate with the state and to work together. Farmers have usually recognized the benefits of collective and communal forms of labour, provided these did not interfere negatively with local production patterns (Newbury and Newbury, 2000: 865-869). The formation of farmer organizations, particularly after independence, served to channel traditional patterns of cooperation and these still feature prominently in the construction of SWC infrastructure today. The building of terraces is organized predominantly through collective labour arrangements.

Over the last thirty years different types of subsidies like food or cash-for-work have been used to stimulate collective labour arrangements in the construction of terraces. Subsidies, however, have always been associated with induced development, inefficiencies and unsustainable outcomes. The experience in other developing countries shows that subsidy induced SWC is often abandoned (Winters et al., 2004; Bunch, 1999). Rwanda has not escaped this phenomenon, and SWC structures that have been abandoned or which are ill-maintained and in dire need of repair are commonplace. The re-investments required for such repairs and maintenance are often beyond the means of farmers. Moreover, the food-for-work and cash-for-work incentives used to develop SWC infrastructure tend to create 'dependency syndromes' and undermine people's efforts to implement SWC measures themselves. Bunch (1999: 216) links the dependency syndrome with the role of the state: 'farmers develop a feeling of paternalistic dependency that they are unable to practice or manage SWC without artificial incentives and continuing assistance'. Newbury and Newbury (2000) trace this paternalism back to the pre-colonial and colonial eras and relate it to the central role of the Rwandan state in development.

Subsidies also transform the dynamics and meaning of 'mutual assistance' and labour relations in Rwanda's rural areas. Cultural repertoires of mutual cooperation and reciprocity are central to communities and to the social relationships between farmers. They are important local institutional building blocks and an essential part of the strategies that farmers employ in order to develop their livelihoods and deal with uncertainties and crises such as difficulty in accessing land and labour (Berry, 1989; Cleaver, 2002). In Rwanda, forms of mutual cooperation often involved alliances forged by local elite groups (e.g. local leaders) since they controlled land and cattle (Newbury, 2001). Over time, the relations that hinged on elite-commoner cooperation became increasingly tied to the state, particularly in the field of land improvement. Both the colonial and post-colonial states have used various means to drive investment in land.

[2] This chapter will be reworked into a journal article

These include direct monetary incentives (e.g. tax policies, cash for work) and in kind incentives (e.g. food for work). This has resulted in commodity dependant labour relations. In addition, the Rwandan state has initiated the formation of farmer cooperatives and organizations over the years. These organizations play a prominent role in the development of SWC infrastructure, such as terraces.

Little is known about farmer organizations and how they function in relation to their members and the agrarian policies of the state. Local people's opinions about the organizations they have joined or formed is something of a mystery. This article aims to contribute to the knowledge about these organizations by addressing two questions. The *first* deals with how farmers perceive their role and participation in the decision making process that leads to the establishment of SWC measures. Given that terraces are constructed under different SWC interventions, the *second* concern of this paper is to find out how farmers perceive the importance of their organizations or institutions in this process and how these perceptions affect SWC strategies in Rwanda. Section two of the paper reviews some of the theoretical links between farmer organizations and institutions, on the one hand, and the particular socio-technical characteristics of SWC structures, on the other. Section three describes the study area and explains why particular research methods were used in the study. In section four, we describe how the Rwandan state has strategically used the customary language of local, traditional forms of organization in order to encourage soil and water conservation. The fifth section presents and discusses the results of the study.

3.2 Organizations, institutions, soil erosion control structures

This paper aims to capture the dynamics involved in the construction and maintenance of SWC structures such as bench terraces. The basic theoretical starting point for such an analysis is the contention that the construction and maintenance of bench terraces and similar devices is the outcome of locally specific interactions between farmer organizations and other institutions. The nature of state-farmer relationships and the particular technical and physical characteristics of SWC structures are important factors. Other factors include the effectiveness of terraces, the economic benefits derived from them and the degree of participation in their construction, maintenance and use. The effectiveness of terracing depends not only on the physical characteristics of the structures but also on the dynamics within farmer organizations and relations between the state and farmers. The opinions of farmers regarding bench terraces are shaped by their experiences during the use, construction and maintenance of these structures, as well as by the nature of the organizational and institutional arrangements that evolve around them. Bench terraces cannot be understood in isolation from their social and institutional environments. Our challenge in this paper is to synthesize several different lines of inquiry in order to make sense of the processes involved. The next section consists of a short review of some of the relevant literature on organizations and institutions as well as an analysis of bench terraces as socio-technical constructions.

Organizations and Institutions

North (1990) describes institutions as the rules of the game in a society, or, more formally, the protocols that shape human interaction. They encompass norms, social values, rules and regulations which shape – but not necessarily determine – opportunities for people to access and utilize resources. Institutions mediate people-environment relations (Leach et al., 1999; Agrawal and Gibson, 2001). Central developmental questions include understanding how such institutions develop, how rules and laws are designed, and more importantly, how they are understood in specific localities. Institutions can viewed, therefore, as normal patterns of behaviour that, as we will see in the second part of this paper, are in most but not in all circumstances accepted by a range of actors (Roep, 2000; Long, 2001; Ostrom, 1990, 2004).

Organizations and associations are the (formal and informal) manifestations of the social structures that societies create to order and guide governance. Usually, organizations have a certain bureaucratic model of governance with appointed and/or elected positions (e.g. chair persons, secretary). While associations 'emerge from below' and are well embedded in local cultural and organisational repertoires (Shanin 1973; Berry, 1993), in contrast and historically, many farmer organizations in Africa (e.g. producer cooperatives) are formed and controlled by the state. The formation of cooperatives has become an institutional vehicle for the state in Africa to stimulate agricultural development and economic growth (Bates, 1983; 1989). In addition, foreign aid institutions like Western states have been funding and sponsoring various state and NGO implemented programmes. The implication is that the nature and direction of local development are shaped, influenced and, at times, determined by national and international processes and actors.

An understanding of organizations and associations, as we have said, is central to our analysis. Such an understanding should be informed by the debates concerning the constitution of communities. The notion of community is often misleading and it is striking the degree to which simplistic notions of community are being reinvented in the context of practical efforts towards community based sustainable development (Fabricius 2004; Leach et al., 1999; Guyer, 1981). Although it assumes a high degree of homogeneity and harmony, the opposite is often the case. As is the case with communities, rural people's organisations and associations have become increasingly disaggregated (McKeon et al., 2004). Like communities organisations are not static either. They are composed of people who, in the struggle for resources, actively monitor, interpret and shape the world around them and create and utilize various alliances. This echoes a perspective that revolves around social actors, agency and action. Structure, or rules and norms, are the product of human practices, actions and interactions. Certain actions may be intended; others may have unintended outcomes (Long, 2001, Van der Ploeg, 2008). The tenant of the political ecology literature is that social behaviour and action is shaped and constrained by the wider environmental, economic, political and cultural institutional frameworks in which social actors find themselves, and by their location within a society (Warren et al., 2001; Zimmerer and Bassett, 2003; Robbins, 2004). While the decisions and actions of actors may well be affected by what happens elsewhere, it does not follow that these decisions and actions are determined by such events. Actions cannot be reduced to the expression of an actor's position within a system of social relations in any simple way. The actions of people are influenced, but not necessarily structured or determined, by outside forces such as markets or the state's agricultural policies. Authors like Watts (2007) and Agrawal and Gibson (2001) stress the importance of unpacking the notion of community and insights emerging from this should be extended to the analysis of (farmer) organizations and associations. Gender, age, social and economic inequalities, unequal access to resources and power differences all contribute to the existence of communities that are socially and spatially differentiated, rather than equal and consensus driven (Arce and Fisher 2003). Agrawal and Gibson (2001) and Mckeon et al., (2004) argue that it is important to focus on the multiple interests of actors within communities and their associations and the ways in which these actors shape decision making processes. Cousins and Kepe (2004), Platteau and Gaspart (2003) and Platteau (2004) highlight the tendency of the so-called 'big men' or local elites and gate keepers of the state to gain control over community and farmer organizations and their development projects.

Recent literature suggests that there is a growing consensus that one way to escape from the simplistic notion of community is to focus instead on institutions (see for instance Ostrom,1990, 2004; Poteete and Ostrom, 2004; Leach et al., 1999). This shift potentially offers a more fruitful approach to understanding what constitutes organizations and how these function practically. There is, however, disagreement in the literature with regards to understanding and interpreting data concerning the governance of institutions and organizations and their dynamics. The major contention is between perspectives that emphasize the normative and structural aspects of organizations and their influence on social behaviour and the relationship patterns between people and their social and natural resources (Uphoff, 1986; North, 1990), and those which present institutions as a set of rules and regulations that provide individuals with room for manoeuvre (Ostrom, 1990, 2004; Scott, 1985; Long, 2001). An institution and organization may thus simultaneously be used to denote a process, an object and a subject. A key question is whether (and to what extent) we attribute power only to those social actors who create institutions and who formulate and maintain the rules to which others feel bound, or whether agency should also be attributed to those with less power.

The distinction between 'formal' and 'informal', which is often made in the analysis of governance and institutions, denotes a difference between what exists in an idealized form on paper and what actually happens in practice. Focussing on what people actually do in their daily lives enables one to identify locally specific forms of organization. (see for instance Mosse, 2004). It allows one to document visible, but also unexpected, practices. Some social scientists (Long, 2001; Moore, 2005; Scott, 2009) link this with issues of agency, fragmentation and power differentials. They point at the many ways in which people skilfully manage to get around laws and regulations and to resist political interventions to defend their own interests. Yet, typically, these informal practices and forms of organization provide people with room for manoeuvre to pursue their individual and collective interests. Van der Ploeg (2008) associates this with resistance of the 'third kind'. The perspectives outlined here do not necessarily reject the notion of community or (farmer) organization, but following Leach et al. (1999: 230) 'rather contextualize it by describing a more or less temporary unity of situation, interest or purpose.' Watts (2007) takes a similar analytical position. Key to any analysis is a firm grounding in the *locality* that places emphasis on how local people and other relevant actors such as policy makers and scientists (including ourselves) read the institutional and physical landscape *and* the changes that occur around them.

Soil and Water Control Structures

The approach taken in this paper is that technologies or engineering devices are artefacts developed by people. The field of technology and engineering has been studied by a variety of disciplines employing perspectives that have ranged from technological determinism and an (neo-classical) economic view of technology development to social-constructivism (e.g. Kloppenburg, 1988) and actor network theory (e.g. Latour, 2005). We will not provide a complete overview of all these theoretical perspectives. Instead, we will formulate a synthesis of the different positions which, we believe, can be used to understand soil and water conservation as structures that are man-made, and which, consequently, contain and reflect codes and assumptions about how to construct and use these structures.

Technology development and transfer necessarily involves an interface between the world of designers and experts and that of the users. Bench terraces are not simply neutral engineering devices but are designed on the basis of assumptions made by engineers about how they should work in particular contexts (MacKenzie and Wajman. 1999; Jasanoff, 2004; Hebinck, 2001, Rip and Kemp, 1998). Technologies are socially shaped: bench terraces can only work (in the eyes of the designers) if they are constructed and maintained in certain ways. When designing terraces, agricultural engineers tend to situate them in hypothetical rather than real societies. Assumptions, for example, about the amount of labour available for construction and maintenance feed into the design. But bench-terraces are socio-technical rather than purely technical constructions. An example of this is when their construction is undertaken by state driven forms of farmer organization.

Terraces are seen as effective technical devices to conserve and improve soil properties and soil productivity in the highlands of erosion prone countries like Rwanda (Posthumus and de Graaff, 2005; Kannan et al., 2010). Apart from terraces, other technologies to protect and improve soils include trenches and contour bounds, water harvesting techniques and planting trees. Numerous studies show that the construction and maintenance of bench terracing entails huge labour and financial investments. This means that it is extremely difficult to erect them on an individual basis. The shortcoming of these studies and classical approaches to soil conservation, however, is their one-dimensional focus on the technical dimension of terrace construction, notably steepness and soil suitability, the lack of any account of the position of the participants (the natural resource users themselves), and the reliance on experts (Biot et al., 1995, see also Blaikie, 1985). While there has been a substantial analytical focus on local knowledge in interaction with expert knowledge (Keeley and Scoones, 2003; Chambers et al., 1989), few studies actually analyze the difficulties of terrace construction and maintenance in the context of the histories of state-farmer relationships and social and institutional arrangements or procedures. Figure 1 shows the interrelation between the social and technical dimensions of bench terraces. The Rwandan state has historically as well as contemporary occupied a central role in the construction of soil and water conservation infrastructure and in the formation of farmer organizations'. The underlying dynamics involved with the construction of bench terraces and organizations and the results of conservation programmes in Rwanda are thus understood in this article as the interplay between the attempts of the state to bring ready-made technologies and institutional frames and codes of conduct (that are expert designed) and the local reworking (or adaptation) of these by local people.

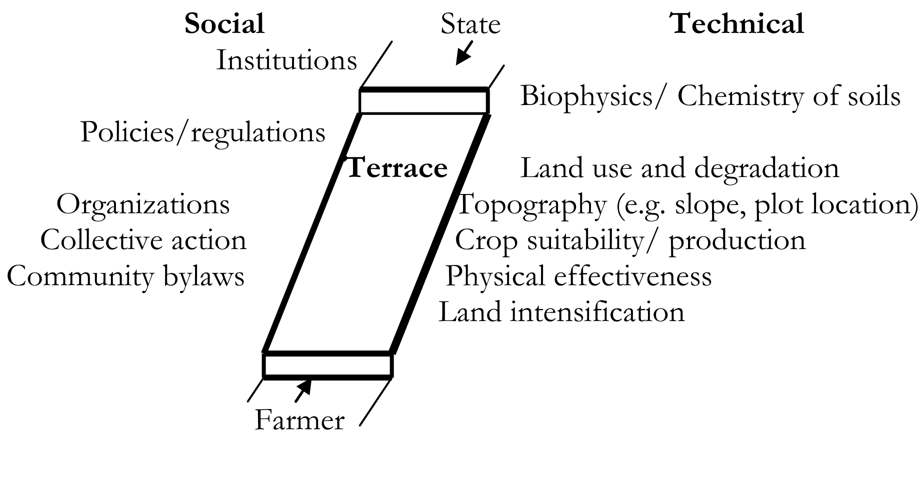

Figure 1: Socio-technical constructions of bench terraces

3.3 Study area and Research methods

This study is based on data obtained from a survey of 301 respondents randomly selected from areas in Southern and Northern Rwanda. The data is complemented with information that resulted from a number of group discussions with members of 20 farmer associations and interviews with key informants at district level. The farmer associations were selected from the 20 sectors that constitute a major part of two agro-ecological zones: the Congo-Crete Nil Watershed Zone (South) and the Buberuka Highland Zone (North). These two zones are hilly and are considered particularly suitable for both bench and progressive terracing.

The field sites were selected on the basis that they belonged to the joint slope category, which is comprised of two groups with gradients of between 12 to 25 and 25 to 55 per cent respectively. The first group in the category is suitable for progressive terraces (PT) while the second is better suited to bench terraces (BT). Using Geographic Information System (GIS) mapping techniques, we mapped the areas in which slopes of these gradients are common and selected 20 out of the 38 sectors in the two zones for our study. One farmer association from each sector was selected for a group discussion. We mapped the SWC structures with farmers in order to identify where bench and/or progressive terraces are located (Figure 2). These locations were geo-referenced by taking GPS points from which the location maps were generated (Figure 3). Finally, about 4 households per sub-catchment/village were randomly selected for detailed interviews.

This paper, as mentioned earlier, undertakes an analysis of farmer organizations, their relationships with the state and their related experiences. The analysis is based on data relevant to the characteristics of association membership, members developmental priorities and needs, the role of mutual assistance, existing policies for soil and conservation, farmer participation and decision making in SWC, types and sources of agricultural advice and perceptions about the effectiveness of established SWC structures. In respect to data analysis, both quantitative and qualitative methods have been used. The aim of this paper, though, is not to provide quantifiable data about the causal relationship between local institutions and soil erosion control, but rather to provide descriptive and qualitative insights.

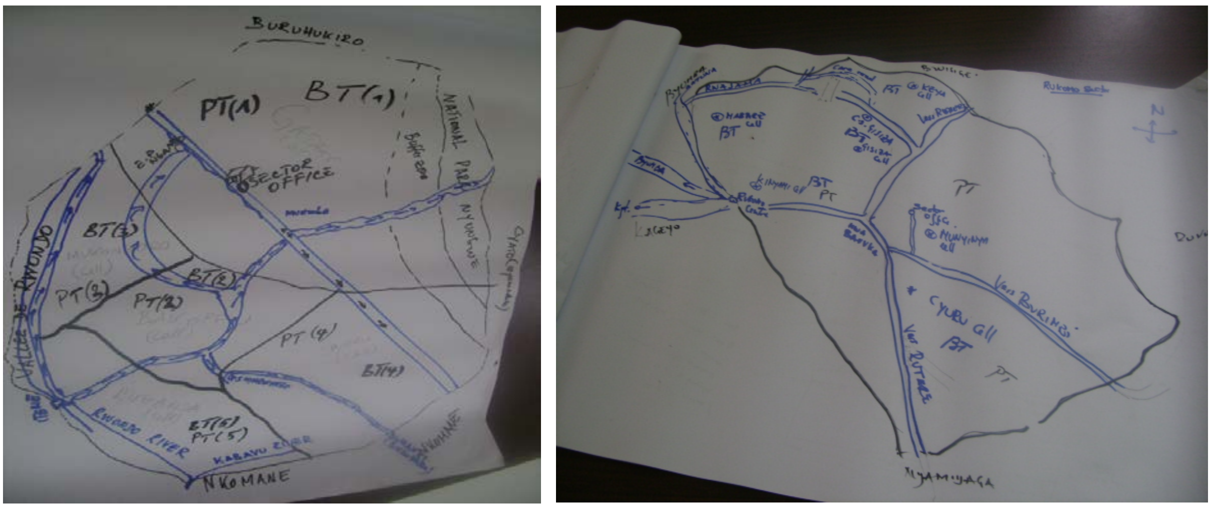

Figure 2: Dominance mapping of bench and progressive terraces by farmers

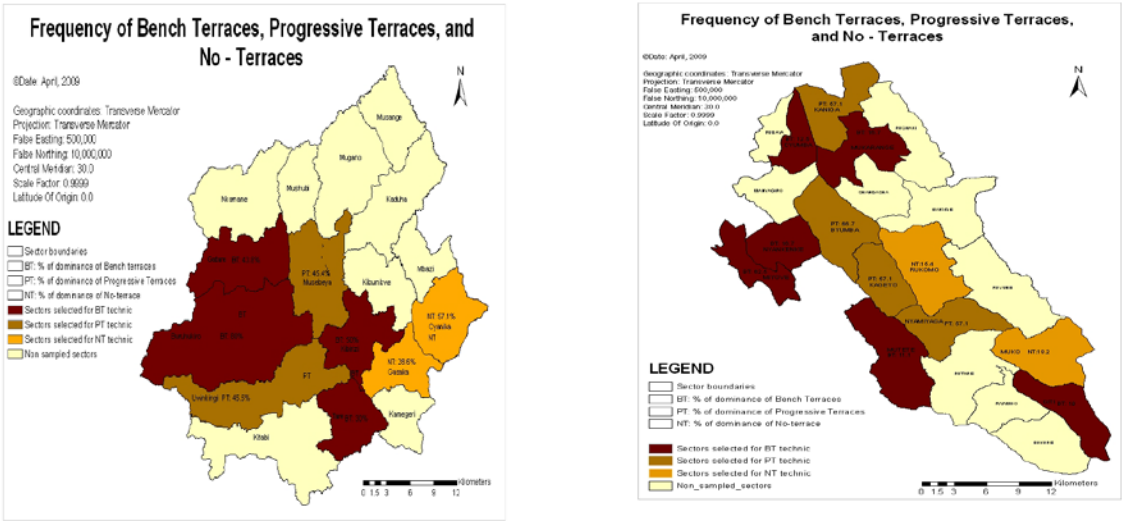

Figure 3: Location of the study sites

3.4 State policies and collective soil conservation in Rwanda

Historically Rwanda's colonial and post colonial governments have played an important organizing role in the implementation of soil and water conservation policies and programmes (Newbury and Newbury, 2000). We will focus on the construction of terraces, the first of which were built shortly after independence was gained in 1962. The change of government led to the introduction of some new methods of controlling soil erosion. Most of the SWC measures that had been introduced during the period of colonial rule were imposed from above; their rejection by farmers after independence may be perceived as an expression of the farmers newly regained freedom. This is certainly the view of Olson (1994). He notes, though, that the 1962 'social revolution' also had other effects on land management. These included the conversion of land that had been reserved for pasture to land for cultivation and human settlement. A political explanation may be that the top-down approach of the colonial government led to techniques which the majority of farmers and technicians did not agree with or trust (Ndindabahizi and Ngwabije, 1991; Guichaoua, 1989; Kayijamahe, 1982). Nevertheless, there is still a remarkable continuity in terms of SWC techniques between the colonial and postcolonial eras. Most of the conservation techniques that were introduced by the colonial regime were maintained by the newly independent regime (Verwimp, 1991). Only hedgerows (for mulching and fodder for livestock) and bench terraces were new additions.

Different approaches to terrace construction have been applied in Rwanda at different times. Initially, terraces were mostly built on public or government land (known as *Ibisigara).* The assumption was that farmers would be attracted to use them. Organizing labour and securing complementary inputs were major constraints, however. These were among the reasons why some of the terraced plots were not fully utilized and maintained by farmers. A response to these emerging problems was to mobilize collective labour to establish terraces on private land. However, the fact that individual plots were scattered within villages and cells (one of the smallest administrative units in Rwanda) limited the large scale implementation of SWC programs, and the approach had to be modified again. Currently there is a two pronged approach based on the realization that bench terraces are ready made constructions which require substantial financial and institutional investments. Slow forming terraces, also referred to as progressive terraces, have begun to be promoted. These are advantageous in that they are built up gradually during the process of cultivation and the simultaneous planting of hedge rows. Slow forming terraces require less labour and financial input from the users. While the overall approach of government is now to encourage both bench and slow forming terracing, bench terraces are still perceived as being superior to the slow forming ones. Mustering labour and resources for the construction and maintenance of bench terraces remains a key aspect of the state's conservation drive. State-farmer relationships, therefore, continue to be essential to soil conservation efforts in Rwanda and to bench terrace construction in particular.

Farmer organizations are an effective vehicle that the state can use to shape its relationship with farmers in order to implement its conservation and agrarian policies. The relationships formed within the farmer organizations in turn nurture collective action and mutual assistance. They enable the pooling of labour and the sharing of farm implements for terrace construction and maintenance. A key research question arises: whose interests are served through these mechanisms? This article argues that while local organizations have been used as a *means* to facilitate the implementation of SWC programmes, they are not the result of the policy or project implementation. It is also true, however, that little is known about how farmer organizations and their members perceive their role(s). The sustainability of the collectively constructed SWC structures is also unclear.

Umuganda, *Imihigo, Ubudehe* and *Agasozi Ndatwa* are policies designed to achieve a range of societal objectives. These include the construction and maintenance of soil and water infrastructure that can simultaneously reduce soil erosion and modernize agriculture. The modern Rwandan state currently taps into traditional forms of collaboration, notably those that adhere to the notion of collectivity and cooperation. These are crucial institutional vehicles to achieve its aim of promoting development. These arrangements are continuously being adapted to accommodate change in Rwanda today. The advent of labour migration, the reorientation of rural livelihoods to incorporate non-agricultural activities and the Genocide of 1994 have all had an impact on the ease and feasibility of organizing labour collectively and calling on the assistance of friends and neighbours.

The term *Umuganda* derives from Kinyarwanda and expresses the idea of building a house collectively. Nowadays it refers to the rallying of communal labour for the reconstruction and repair of basic public development infrastructure under the supervision of village heads. *Umuganda* requires everyone to contribute free labour, even the president of the state and other political leaders. *Umuganda* is rather similar to the notions of *gotong royong* in Indonesia (Bowen, 1986) and *Salongo* in the Democratic Republic of Congo during the Mobutu regime (Adelman, 1975). *Umuganda* is mainly called on in SWC in order to construct and repair water canals and irrigation systems. It is also used for the implementation of water harvesting techniques such as *ibitega*, tree planting and, occasionally, the construction of trenches and bench terraces.

Imihigo draws its meaning from mutual promises meant to increase social capital, civic awareness and political efficacy. *Imihigo* was initiated at the end of 2005 and entails a performance contract between the state and communities to facilitate the implementation of SWC measures, crop production and other developmental goals. In terms of soil erosion controls specifically, each district pledges a number of hectares of land to be protected from soil erosion on a yearly basis. Evaluations are done annually by the central government. Good performances, as defined in the service contract, are rewarded. *Imihigo* also promotes the notion of vertical accountability between local communities and the central government.

Ubudehe also builds on the Rwandan experience and cultural value of collective problem solving. It was initiated towards the end of 2001 with the objective of enforcing collective action at village or community level in order to alleviate poverty. It is considered a pillar of the ongoing political and financial decentralization process. Local people at cell level, the last but one administrative unit in Rwanda, are provided with interest free financing in order to implement locally designed projects aimed at poverty reduction. The reduction of poverty is the main motivation for the reactivation of this traditional arrangement. Mr Kayira ,the *Ubudehe* programme coordinator at the Ministry of Local Governance at the time, confirmed in an interview with IRIN (2005), that 'the most important element in this programme is not the money they spend but treasuring the spirit of local communities coming together design their own strategies and address their day-to-day problems [sic]. This process nurtures also concepts of collective problem identification and solving, and collective benefits [sic]'. *Ubudehe* also sustains other policies of the Ministry of Local Government and the National Programme for Poverty Reduction at the Ministry of Finance and Economic planning. The extent to which the *Ubudehe* initiative has achieved its aim of being all-inclusive requires further detailed study.

Agasozi Ndatwa was launched in 2008 by the Ministry of Agriculture in collaboration with the Ministry of Local Government. This is an extension policy that is being implemented at village level in the administrative unit known as *Umudugu*. The aim is to jump-start self improvement activities on one 'model hill' in each *Umudugudu*. It involves all issues and activities related to land management, such as the prevention of soil erosion, agricultural intensification, animal husbandry, water management, kitchen gardens and land consolidation. *Agasozi Ndatwa* is also performance based and complements other development policies at the 'hill' level, such as those related to education and health. Administrative units and model farmers are provided with awards in order to encourage competitive land management and soil erosion controls.

These measures demonstrate how the state skilfully draws on the traditional repertoires of local forms of organizations in order to address the developmental issues of modern Rwanda. The new institutions it encourages or forms are based on a blend of the 'traditional' and the 'modern'. This institutionalization process does not only build on and enforce the idea of collective action, mutual assistance and the mentality of self-reliance, however, it also fosters a spirit of competitiveness. The challenge for researchers is to analyze the properties that emerge from this blend of new and traditional practices. Another important issue that needs to be addressed is the way in which farmers are responding to the initiative and learning from it. Farmers, after all, are at the centre of the programme.

3.5 Farmer cooperatives and associations at work

The analysis of the data collected reveals how the farmers who participated in the interviews and group discussions perceive their organizations and their role in soil conservation. It also identifies the development needs expressed by farmers and how these are addressed through their institutions. Opinions about the effectiveness of the terraces that were established in the past also emerge.

Characteristics of farmer associations

This sub-section describes some major characteristics of the 20 farmer associations that were sampled to get an idea of their role in soil conservation and how this relates to the modalities of the project and state interventions. Both the survey and the group discussions confirm that farmer associations have been part of the institutional framework of Rwanda since the 1980s. The formation of these associations was, however, mostly driven by farmers, a fact confirmed by 68 per cent of the 20 associations that were sampled. At first sight this is not consistent with the usual understanding that farmer organizations in Africa are almost always initiated and formed by local leaders, church leaders and agents of the state in order to facilitate the implementation of agrarian policies. But the farmers also confirmed that many of the activities in which their associations engage are shaped by leaders. These include the implementation of soil erosion control measures and training. The associations that we sampled had an average of 41 individual members each. It appeared that the membership of some associations fluctuates. Most associations suffer from a lack of the skills that are required to manage their daily activities. Few of their members have completed primary school. Consequently they have to rely mostly on their own knowledge and experiences and on the informal skills that they have obtained from agricultural training, field visits and meetings held with local leaders. Figure 4, drawn from survey data, shows a relatively positive trend in relation to association membership since 1975.

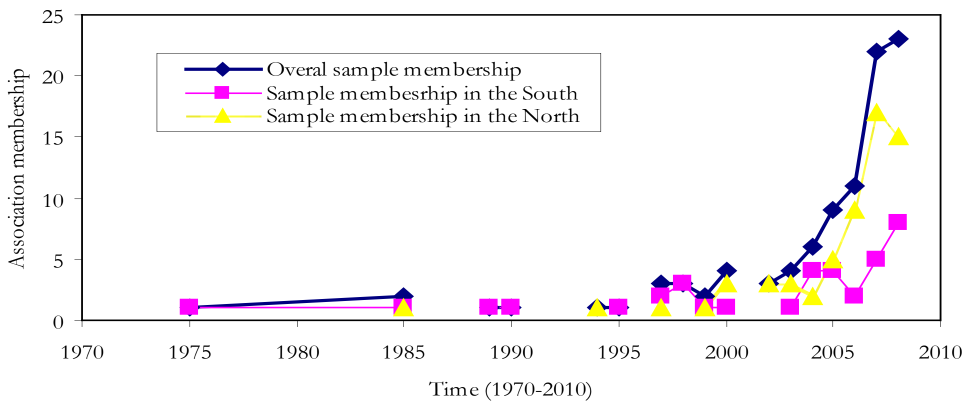

Figure 4: Trend of association membership in Southern and Northern Rwanda

The operational capital of the organizations is generated by the collection of membership fees (*ubunyamuryango fatizo*) as well as from income derived from the collective or contractual activities that members perform on behalf of their associations. Operational capital is about 1.200.000 FRW per year (about $ 2.000). These operational funds are used to finance joint crop production at association or cooperative level. Farmers maintain that this is not sufficient to cover their needs. Bingen and Munyankusi (2002) draw a similar conclusion.

Two different types of farmer organization in the research area can be distinguished, each operating at a different level. At sector level, a third level administrative unit, informal and formal organizations can be identified. It should be borne in mind, though, that writers such as Cleaver (2002) are critical of such distinctions since it is difficult to accurately identify all the different organizations that are socially embedded in communities. The first so-called 'informal' category consists of small groups, known as *amatsinda*. These are small-scale and multi-purpose associations. Some of them are only active temporarily. They are based on kinship and locality and serve to respond to daily issues. These small-scale associations, begun in the 1980's, are still the organizational structure that most farmers prefer. The 'formal' organizations consist of cooperatives and have been backed by the government since 2006. The formation of these cooperatives stems from the need to receive recognition as a legal body in order to get access to more lucrative services such as financial loans. The government has set criteria that small associations have to meet if they wish to become cooperatives, but many of these associations are not able to comply with these criteria. Moreover, the shift to formal cooperatives has produced complaints regarding the low levels of trust between cooperative members, in contrast to the greater levels of trust that exist in the less formal associations. Social interactions are more complicated in the cooperatives since they amalgamate people from several smaller associations and from different areas. This partly explains why small-scale associations are still dominant in the rural areas. 54 per cent of the 101 members surveyed belonged to small-scale associations as compared to 19 per cent who were members of the cooperatives.

Major development needs and mutual assistance

Table 1 summarizes the major development priorities and daily needs that were brought forward during the group discussions. These needs have customarily been addressed by social arrangements such as mutual assistance (known as *gufashanya* in Kinyarwanda). Mutual assistance is the engine that sustains the pooling and sharing of labour from individual farmers. It allows them to solve labour shortages in relation to the establishment of soil conservation measures. Bench terracing is a labour-intensive activity. Terraces are difficult for individuals or families to construct on their own. Many households attribute their success in constructing bench and progressive terraces on their individual fields to collective arrangements.

The sharing of labour has also led to practices such as '*twibature*' and '*abahwituzi*'. *Twibature* is especially common in the North. Certain farmers (known as *Abahwituzi*) get up at five in the morning and wake up the rest of the people in the village. Work is then begun on terracing the hill that has been selected under the new policy of *Agasozi Ndatwa*. In most cases, people cultivate terraces collectively and share the harvest. The reciprocity entailed in these relationships has become part and parcel of the socio-technical grammar required for the construction of bench terraces. Both the inherent costs and benefits of terrace construction and maintenance are shared.

Table 1. Major daily needs mentioned in group discussions

Lack of potable water
Electricity and access to health services
Insufficient livestock to provide manure
Lack of liquidity to financially support farming activities including soil erosion controls
Lack of access to markets, agricultural inputs and credit
Unpredictable climate and climate change
Small field sizes

Source: Focused group discussion

Farmers in the north report that access to water is a real concern. They have to fetch water over long distances. Others rely on harvested water but the relevant infrastructure is limited. Access to electricity and health services is also irregular. Farmers assist each other through their associations. They might for instance contribute financially to the purchase of a membership card for the health insurance scheme known as '*mutuelle de* *santé*. Farmers pay about 10 to 15 per cent of the costs of the treatment with this card. It is difficult for farmers to generate money to support their farming activities and home expenses because opportunities for off-farm income generation are limited. Most farmers have small and fragmented fields (less than one hectare in most cases). One result of this is that soil conservation practices such as fallowing are disappearing.

Two-thirds of the associations whose members were sampled identified problems with accessing agricultural inputs. The prospect of climate change was another major issue that was frequently mentioned. Mutual assistance plays an important role in dealing with these sorts of issues. Farmers lend and borrow money from one another by means of a system that they call '*Ikimina'*. This helps them to circumvent the banks and local money lenders. Trust, honesty (*ubunyangamugayo* or *ubupfura*) and the shared notion of mutual assistance ('*umutima wo gufashanya*') are the collateral in such exchanges. '*Ikimina*' allows farmers to purchase inputs and/or pay health insurance and school fees for their children. In addition, farmers share agricultural inputs such as labour, seeds, fertilizer and manure, and exchange agricultural experience. Some farmers even go so far as to lend their cattle to their neighbours so that they can get manure to improve their acidic soils. Sharing cattle, known as '*inka ya kaguru'*, is a practice which dates back to pre-colonial times (Newbury and Newbury, 2000). The owner of the cow also benefits since he does not have to purchase as much feed as usual. The neighbour has the use of the milk and might get a young calf as well. Forms of mutual support such as these are an important characteristic of the social relations between association members.

Effects of induced soil erosion control

We investigated whether the SWC structures that were created through these labour arrangements were well constructed and whether they produced both short and long term benefits such as better soil and water conservation and increased soil fertility and productivity. We also explored whether or not individual farmers were involved in deciding when and where to establish infrastructure such as bench terraces. We asked farmers to compare terraces that were built before 2006 with those that have been built since. Many international and local NGOs were actively involved in the development of SWC structures in the period before 2006. Research shows that farmers were only marginally involved themselves during the planning stages of these projects (Bingen and Munyankusi, 2002; Bizoza et al., 2007). They were mobilized with food-for-work incentives in order to provide labour and to make their land available for terracing. On the whole, they were more interested in getting part time jobs than in soil erosion control. The short term incentives distorted farmers' perceptions of SWC (Pretty and Shah, 1997). As a result, little attention was given to the maintenance of the terraces constructed in the research area before 2006, especially after the genocide in 1994. Since poorly made and maintained SWC structures affect soil properties and lead to nutrient depletion (Lewis, 1992; Pretty and Shah, 1997; Fleskens, 2007), the state and other development agencies have committed themselves to supporting the repair of old terraces before they are utilized again by farmers. The cost of repairing a bench terrace, however, is often higher than its initial construction cost. These costs are not only monetary but include the loss of soil nutrients and fertility due to soil disturbance. Farmers point out that if they are to make disturbed soils productive again they will have to be supplied with more manure and fertilizers than usual.

Support programmes before 2006 were generally inadequate. The group discussions provided us with some key aspects that characterized the *modus operandi* of SWC in this period. Farmers describe how some of them were recruited by the support programmes to construct terraces before they had received relevant training. Supervision and guidance were mostly provided by their own representatives, known as *abagapita*. It was incorrectly assumed that these people were familiar with the necessary construction techniques. Some terraces were constructed without technical consideration for factors such as the appropriate slope gradient relative to the available area. There was also a lack of attention given to matters of terrace outlining, such as the shape of the bed and the terrace riser or '*umukingo*' as well as the type of risers and the species of grasses planted on the risers (e.g. *pennissetum*). Insufficient effort went into saving top soil with the result that the soil fertility of many terraces will now take a long time to restore. The selection of sites was also identified as a problem. Some sites were chosen simply on the basis that they were conveniently located for evaluation visits. Other terraces were constructed on plots that belonged to the government (e.g. *ibisigara*) or big farmers on the assumption that the users would cultivate and maintain them with the assistance of their associations. This was, however, not always the case. Organizations like World Vision International constructed terraces near homesteads, but this was also problematic since houses are widely scattered across the hills.

In contrast, the bench terraces that have been made since 2006 are perceived to be technically better and more productive. Farmers have become more aware than they were in the past of the importance of saving and spreading nutrients on the terraces. While they were previously reluctant to make their fields available for terrace construction, their improved understanding of the problem of soil erosion has motivated farmers to build terraces through contracts with their associations. Payments are sometimes in cash but some farmers will help construct a terrace in exchange for the right to cultivate the terrace for two to four cultural seasons. Certain farmers have not only adopted the technique of terrace building but have also begun playing extension roles. Some farmer associations encourage their members to protect their fields by employing appropriate SWC measures. Many farmers are currently re-adopting the SWC techniques, such as bench terraces and trenches, that they previously rejected despite the subsidies that were On offer at the time.

Perceived farmer participation and decision sharing in soil conservation

Gauging the degree to which farmers are involved in soil conservation is not easy. Participation levels have to be measured at the different stages of SWC project implementation: the decision making process, implementation of SWC programmes, sharing of benefits and the evaluation of the programmes (Oakley, 1991). Winters et al. (2004) and Posthumus (2005) examine farmer participation in the implementation stage as a discrete variable: participant or non- participant. This view of participation hinges on whether or not a farmer is selected for the programme and whether or not he receives benefits. Whether or not a farmer provides labour is also treated as a key variable. Mansuri and Rao (2004) argue that an analysis of genuine participation requires more than this. They maintain, for example, that the incorporation of farmers' knowledge in the design of SWC is a critical dimension of farmer participation. Vigiak et al. (2005: 309) refer in their study in Tanzania to a number of studies that document the importance of farmers' knowledge in the assessment of soil fertility, landscape processes, the relation between soil productivity and relief position, and erosion assessment. They argue in line with the neo-populist paradigm (see Blaikie, 2000) that "the incorporation of local knowledge in erosion assessment offers many advantages for SWC planning".

In our study, we have explored farmer participation in relation to shared decision making when establishing bench terraces in the research area. We have focused particularly on the role of farmers in the decision making process during two major phases of the process of terrace construction. The first relates to the decision regarding *when and where* to construct bench terraces in communities. The second relates to the *criteria for site and beneficiary selection*. Farmer participation at this stage of SWC means that they have a share in the decision-making process regarding the construction of bench terraces. This is often described in terms of ownership of the programme or project. Farmer participation and decision sharing have the potential to translate into farmer ownership of the existing or future SWC infrastructure and may help to ensure its sustainability. We have used the survey to gauge farmer perceptions about their ownership of SWC projects. Table 2 presents data that reflects the proportion of the perceptions of farmers regarding when and where to construct terraces. Out of 301 survey respondents, 47 per cent maintain that local leaders at the village and sector levels decide when and where to construct terraces. Only 41 per cent of respondents state that farmers themselves make these decisions. Analysis of the number of local leaders involved as compared to farmers themselves, reveals that the mean difference is positive and statistically significant at 15 critique level (t = 1.17). Comparing local leaders to extension agents (t= *3.82*) and farmer associations (t=13.03), the mean differences are also positive and statistically significant even at a critique level of one per cent.

Table 2. Decision makers with regard to construction of terraces

Decision makers	South Nyamagabe		North Gicumbi		Overall study area	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Local leaders	36.0	0.48	56.1	0.49	47.0	0.49
Farmers themselves	37.5	0.49	44.5	0.51	41.2	0.50
Extension Officials	43.4	0.54	22.6	0.41	31.0	0.48
Farmer Organizations	6.6	0.25	3.7	0.18	5.0	0.22
All together	11.8	0.32	10.4	0.30	11.0	0.31
Total respondents (*n*)	136		165		301	

Source: own survey

Table 3 indicates the criteria that are followed when it comes to the selection of sites for terracing and also the beneficiaries of these terraces. 64.9 per cent of farmers view the identification of places with soil erosion risks (64.9 per cent) as the dominant factor in the selection process. 33.8 per cent consider government regulations to be the chief factor. Only 12.4 per cent maintain that the community is consulted before terrace construction. These descriptive statistics suggest that most of the terraces that are constructed are supply driven and that farmers do not participate in the decisions regarding where and when to construct them. When farmers do participate, it is mostly only through some consultation and their own efforts to mobilize collective labour for the construction of the terraces (see also Pretty, 1995). Once again this underlines the fact that the state plays a prime role in SWC and that the role of extension agents and farmer associations is marginal. The latter are meant to sustain the vertical links between individual farmers and state agents. The data suggests, however, that rather than involvement at the planning stage, their role is limited to mobilizing labour and, sometimes, to identifying land for terracing. Agronomists attached to the extension services provide advice at each sector level. They have little contact with farmers, however, since agricultural advice is only one of their responsibilities. Community representatives (*abagapita*), most of whom are members of the farmers' associations themselves, have been trained to provide additional support and advice to farmers.

Table 3. Criteria for site/Beneficiary selection

Criteria for selection of sites and beneficiaries	South CNWZ(Counts)	North BHLZ(Counts)	Study area (Counts)
Soil erosion risk	63.2	66.3	64.9
Self interest in the available land	19.1	14.7	16.7
Government regulation	31.9	35.6	33.8
Interest of support programmes	18.4	8	12.7
Community consultation	9.6	14.7	12.4
Farmer organization membership	2.2	1.8	2.0
No transparency	3.7	3.1	3.3
Don't know	16.9	10.4	13.4
Number of observations (N)	136	165	301

Source: own survey

Table 4 shows the extent to which the government's new policies for collective soil conservation have been acknowledged or implemented by farmers. The policies aim to promote the idea of self-reliance with regard to the construction and maintenance of bench terraces. The *Ubudehe, Imihigo and Agasozi Ndatwa* policy initiatives all began between 2001 and 2008. Only the *Umuganda* policy is older. Most of the policies have not been in place long enough to analyze their impacts accurately. The survey data does give an idea, however, of their relative importance in encouraging farmers to participate collectively in development projects, including soil conservation. 73.8 per cent of respondents know about *Umuganda* compared to *Ubudehe* (52.3 per cent), *Imihigo* (52.5 per cent) and *Agasozi Ndatwa* (68.4 per cent). One explanation is that *Umuganda* was implemented in the 1950s. It is also incorporated into the *Imihigo* performance contracts and the *Agasozi Ndatwa* policies. *Agasozi Ndatwa* is an indication of the key role played by local leaders and other important citizens. Unlike *Ubudehe* and *Imihigo*, both *Umuganda* and *Agasozi Ndatwa* attempt to use farmers' collective labour and mutual assistance arrangements in order to control soil erosion. The number of respondents who recognize the importance of these four policies is an indication of the success of the state in its role as a driver of development.

Table 4. Recent policies for SWC and agricultural development (N=301)

Policies that aim to implement soil erosion	South_Nyamagabe (Std.Dev)	North_Gicumbi (Std.Dev)	Study area (Std.Dev)
Ubudehe	68.4 (0.47)	39.0 (0.48)	52.3 (0.50)
Imihigo	43.4 (0.49)	60.0 (0.49)	52.5 (0.50)
Umuganda	68.4 (0.46)	78.2 (0.41)	73.8(0.44)
Agasozi Ndatwa	61.8 (0.49)	73.9 (0.44)	68.4 (0.45)

Note: Answers were pre-coded
Source: own survey

Farmer associations and support programmes

There are different ways in which the relationship between farmer associations and their respective partner institutions can be analyzed. Stakeholder or network analysis, which has its origins in network theory, is one such way (Ellis and Biggs, 2001; Clark, 2008; Mitchel, 1974). It helps to achieve an understanding of the ways in which stakeholders operate at the level of the individual, the organization, the institution and the community (Morgan and Taschereau, 1996; Brugha and Varvasovszky, 2000; Ridaura, 2005; see also McKeon et al. 2004). This sort of analysis provides insights into the characteristics of stakeholders in terms of their behaviour, intentions, inter-relationships and interests as well as the influence and resources that they pool in order to achieve common goals (Brugha and Varvasovszky, 2000; Grimble and Wellard, 1997). The network analysis that we conducted reveals the nature and intensity of the linkages between farmer associations, support programmes and agencies. It shows how these are distributed across the study area. Farmer associations were also asked to identify the support programmes or partnerships that they could draw on in their efforts to combat soil erosion. Table 5 shows that support programmes are not equally allocated between farmer organizations and/or sectors in the study area. Those nearest to the towns or the District administration receive more SWC support (more or equal to 2 SWC projects) than those in more remote sectors (with less than 2 SWC projects). This corroborates the findings of Bingen and Munyankusi (2002). Their macro-level study concluded that NGO support to farmer associations was not evenly distributed among or within the provinces of Rwanda. The accounts of farmers and the survey data reveal some of the explanations for this situation. Firstly, farmers are tied to or dependent on the plans and priorities of their local leaders. The attitudes of local leaders towards support programmes and their links with such programmes are crucial. Secondly, farmer associations base their demands on their knowledge of what potential supporters can deliver (see also Mansuri and Rao, 2004). Thirdly, support programmes often go into areas in which it is easy to work regardless of the priorities of farmers.

Table 5. NGOs and SWC projects in the study area

Intensity / Area (AGEZ)	South (CNWZ)		North (BHLZ)	
	Sector	SWC projects	Sector	SWC Projects
High ($n \geq 2$ SWCP)	Kibirizi	5	Nyankenke	3
	Uwinkingi	2	Nyamiyaga	4
	Gasaka	3	Miyove	2
	Cyanika	6	Kageyo	2
	Tare	4	Cyumba	3
	Musebeya	2		
	Gatare	3		
Total 1	7	25	5	14
Low ($n \prec 2$ SWCP)				
	Buruhukiro	1	Rukomo	1
			Giti	1
			Muko	1
			Byumba	1
			Mukarange	1
			Kaniga	1
			Mutete	1
Total 2	1	1	7	7

Source: own survey

Table 6 shows the present support programmes/institutions and their areas of operation. The types of programme were identified in the focus group discussions with farmers. Terrace construction, terrace maintenance and farmer training activities receive by far the most attention. In contrast, the supply of credit to enable farmers to acquire agricultural and other productive inputs and to market their crops receives little attention, despite the fact that farmers view this type of support as critical to the success of their efforts to improve and maintain their terraced land.

Table 6. Possible areas of intervention by support programmes

	Possible areas of intervention								
Program/institution	Community. mobilization	Farmer training	Extension	Input marketing	Marketing crops	Terrace construction	Terrace maintenance	Input-output credit	Credits
Government officials	*		*	*		*	*		
UNICOPAGI				*	*				
Vi-Life project	*	*				*	*		
HPI									
World Vision International		*	*			*	*	*	
MIG		*							
RADA							*	*	
PDCRE							*		
PAPSTA							*		
ISAR		*	*						
Bank Populaire									*

Source: own survey

We also asked farmers where they normally seek and receive agricultural advice and related services. Table 7 and Figures 5.1 and 5.2 (see appendix 1.4) summaries the answers we received. Farmers living near towns get agricultural advice easily from local leaders and extension agents. Those in remote sectors tend to seek advice from their neighbours, family members and association members. Figures 5.1 and 5.2 represent the existing linkages between farmers and support programmes/institutions. Our respondents were drawn from four areas: two that were close to big centres and two that were situated in remote districts. The results confirm that distance is an important factor in the uneven distribution of support for soil conservation in the study area.

Table 7. Sources of agricultural advice

Where do you get agricultural advice?	South Nyamagabe	Std. Dev	North Gicumbi	Std. Dev	Study area	Std. Dev
Neighbours	42.8	0.65	83.6	0.37	65.4	05
Far. Association	17.3	050	44.8	0.89	32.5	0.7
Extension Officials	65.4	0.52	29.7	0.46	45.6	0.52
Local Leaders	46.9	0.50	0.6	0.07	21.2	0.40
Private Dealers	2.2	0.14	3.6	0.18	3.0	0.17
Family members	37.6	0.19	67.3	0.97	38.9	0.80
Observations (N)	135		166		301	

Note: Answers were pre-coded , Source: own survey

3.6 Conclusions

We maintain that soil conservation in Rwanda can only be properly understood when situated in the context of evolving state-farmer relationships. Opinions regarding bench terraces are formed not only on the basis of relevant technical matters. The dynamics of farmer associations and organizations and the relationship between farmers and a range of support agencies, such as NGO's and extension agents, are also critical factors that need to be taken into account. Farmers' perceptions of the effectiveness of established bench terraces vary depending on the period in which the terraces were built and the nature of the intervention that led to their construction. The study shows that problems in accessing agricultural input-output markets are a major concern and have hardly been addressed by the multitude of government and NGO designed programmes. Local forms of organisations hinging on mutual assistance and reciprocity among farmers and other members , on the other hand, is a key element of the ability of farmers to deal with everyday problems, including those of soil erosion. Mechanisms such as food- or cash-for-work to establish SWC are not sustainable in the long term. Farmers view limited participation in decision-making in soil and water conservation. They are most likely to contribute to the construction of soil erosion control measures on their own initiative, or after they have been properly consulted. Local leaders play a major role as an extension of the central state when it comes to land improvements and the planning of SWC. The role of farmers and extension agents, by contrast, has been a rather marginal one.

This paper underscores the value of a socio-technical and institutional analysis of soil conservation endeavours. The need to include a critical analysis of the role of the state in land conservation is clear in the Rwandan case. The state skilfully deploys a language of development in conjunction with various institutional arrangements that are derived from the traditional organization of Rwandan society. The intention has been to encourage an attitude of self-reliance and reduce the dependency that was created by SWC projects in the period between 1994 and 2006, while also retaining central state control over the politics of land. However, neither developmental discourse nor the use of traditional social structures can guarantee that conservation measures will be implemented as planned, or that they will be sustainable.

CHAPTER 4

FINANCIAL COST- BENEFIT ANALYIS OF BENCH TERRACES IN RWANDA[3]

4.1 Introduction

Background

Soil erosion and declining soil fertility are major concerns for agricultural development in Rwanda. About 77 percent of the land suffers from moderate to severe erosion (Rwanda Agricultural Development Authority, 2005). Efforts for soil erosion control have been made since 1930s. Currently farmers receive support from government and non-government programmes to construct bench terraces in order to minimize soil erosion on their farms. This technique is generally considered to be effective to combat soil erosion and to maintain water and soil nutrients (Posthumus and de Graaff, 2005; Fleskens, 2007). But these terraces entail huge investments in labour and operating costs for both construction and maintenance (Winter-Nelson and Amegbeto, 1998; Ndiaye and Sofranko, 1994; Pannell, 1999). Alternative labour payment mechanisms such as food-for-work and cash-for-work (Abbott, 1992; Pretty and Shah, 1997) have been used in Rwanda and Ethiopia to induce farmers to address soil erosion through terracing (Barrett *et al.*, 2004). Bench terraces have been introduced in Rwanda since 1970s and received much attention due to many GO and NGO interventions after the 1994 war and genocide. World Food Programme and World Vision International with USAID support are the main organizations that worked with farmers to construct bench terraces in many parts of Rwanda after 1994 (Bizoza *et al.*, 2007). Due to food shortages and poverty, farmers participated actively in building these terraces to gain food rations and cash for their labour input. Not soil erosion control but these food rations and cash were the main reasons for many farmers to participate (Bizoza, 2005). Of the 17,482 ha of existing terraces, 56.3 percent was built before 2006 compared to 43.7 percent constructed during 2006-2007 under the government performance contract '**Imihigo**' (Ruhigana, 2008). Through such contracts the construction of SWC measures and other agricultural development activities are facilitated. Little attention was paid to coordination between different actors in soil erosion control and this resulted in many duplications. Currently the government is taking the lead to reinforce the implementation of the same technique and yet field observations show that many terraces are not (fully) used by farmers (although there are no reliable figures yet on terraces that are not used). This constitutes a problem in a country where land scarcity and high population density (376 inhabitants /km^2) are evident. In addition, Rwanda has many soils with a mostly acidic B-horizon, which comes to the surface after terracing. On unused terraces soil properties are affected and crop yields deteriorate, unless continuous maintenance is ensured (Lewis, 1992; Fleskens, 2007). This maintenance requires for instance proper liming to account for the acidity of these soils but this in turn needs sufficient liquidity which

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farmers have difficulty to afford. Consequently, some plots receive soil conservation measures and others not (Clay *et al.*, 1998; Ndiaye and Sofranko, 1994).

Soil conservation programs often work with farmers in a collective mode and expect that they will adopt, use, and maintain soil conservation measures beyond their intervention period. Experiences from the Philippines, Nicaragua, Ethiopia, Tanzania and Kenya have shown the opposite (Pannell, 1999; Lutz *et al.*, 1994; Tenge *et al.*, 2004). Local perceptions of soil conservation practices are distorted due to short-term incentives paid to farmers through such collective actions (Pretty and Shah, 1997). Likewise, greater costs of conservation than expected benefits, uncertainty of land tenure, and misguided efforts of earlier interventions in soil conservation restrain farmers to construct and maintain existing terraces (Pretty, 1995; Ndiaye and Sofranko, 1994; Pannell, 1999). To a certain extent incompatibility of this technology with prevalent socio-economic conditions of farmers and its inconsistency with farmer's objectives explain low adoption rates and use by farmers (Tenge *et al.*, 2004; Pannell, 1999; Lu and Stocking, 2000). Terracing is largely being implemented for soil erosion control without a proper maintenance strategy, which is a risky investment. For instance the government has availed about 2000 USD for each District in 2007 to construct or maintain existing terraces. Yet, quality of their construction and maintenance needs higher consideration (Lewis, 1992; Fleskens, 2007). Farmers have already started to cultivate on some of these terraces. But little is known about whether farmers find better returns from cultivating plots with bench terraces compared to those with slowly forming or progressive terraces or plots with neither bench terraces nor slowly forming ones. The latter, in East Africa also referred as **Fanya juu**, are initiated by digging a ditch and throwing the excavated soil upwards to form a bund, which by trapping sediment will gradually develop into a terrace.

Therefore, this study opts for a cost-benefit analysis approach to assess under which socio-economic conditions bench terraces are profitable in the Southern and Northern provinces of Rwanda (Dinwiddy and Teal, 1996; Gittinger, 1982; Kuyvenhoven and Mennes, 1989). The remainder of this paper is organized as follows: Section 2 gives some conceptual issues of cost-benefit analysis being the main analytical tool. Section 3 describes the research area and methods for data collection. And section 4 presents results and discusses major findings, and this is followed by conclusions.

4.2 Cost- Benefit Analysis: conceptual issues

Whereas the concepts behind Cost-Benefit Analysis were already developed in the 19^{th} century, the actual technique was devised in the 1930s and it was firstly applied in the USA for large water development projects. Since then, the technique has been used in many other related fields to indicate whether benefits of undertaking a given activity exceed their costs. These benefits and costs are of different types as domains of application vary also considerably. CBA has been used in many agricultural related research and development projects to inform on project efficiency (e.g. Posthumus and de Graaff, 2005; Lu and Stocking, 2000; Tenge, 2005; de Graaff, 1996). The scale mostly considered in agriculture is the field level. The objective of the CBA at this level is 'financial analysis'. It is used as a decision tool after computing all costs against benefits valued in local currency to come up with a 'net benefit' or a 'net income' (Gittinger, 1982). Better quantification of cost-benefit variables is crucial for better decisions. Simply stated, the aim of using financial CBA is to find out whether a given activity or project intervention is financially profitable for participants. CBA has also been used to relate costs and benefits to adoption rates of soil conservation measures such as bench terraces. Technology adoption is not entirely explained by its profitability but also by many other factors (Ervin and Ervin, 1982). A broader analysis is compulsory to capture other determinants of adoption (Lutz *et al.*, 1994). Apart from private or financial CBA, as applied in this paper, economic CBA and social CBA are used to determine costs and benefits of a certain project beyond the private perspective. Then a society or the national level becomes the basis for analysis (for details see: Kuyvenhoven and Mennes, 1989). Net Present Value (NPV) and Internal Rate of Return (IRR) are commonly used as decision criteria for determining profitability at both the activity or project level and at the national level (Abelson, 1996; Kuyvenhoven and Mennes, 1989; Gittinger, 1982), and are briefly discussed below.

Decision criteria
Net Present Value (NPV)

The Net Present Value (NPV) compares the total benefits and total costs for a certain period and discount rate. Discounting translates future costs and benefits into present values. The discount rate applied should represent the opportunity cost of capital. As with other investment criteria, its choice entails possibly two types of errors in choosing a profitable project among others: a very high discount rate decreases the NPV and may lead to rejection of a project which might be a good one and vice versa. A positive NPV indicates a positive net benefit. In case of mutual exclusiveness the project with the highest (positive) NPV is favoured, other things being equal. The formula is:

$$NPV = \sum_{t=1}^{n} \frac{(b-c)_t}{(1+r)^t} \qquad [\,1.1]$$

Where b stands for benefits and c for investment and recurrent costs. The super and subscripts represent respectively future and current time while r stands for the discount rate at time (t).

Internal Rate of Return (IRR)

The alternative decision criterion to choose a profitable project is the Internal Rate of Return (IRR). This is the rate which renders the NPV to be zero. When the IRR of a project is greater than the discount rate, then the NPV of that project is positive. In decision terms, the project is acceptable. Occasionally IRR and NPV may yield a different ranking of projects. Two remarks can be made: - the size of projects matters in calculating NPV: large projects with high costs and benefits are likely to have higher NPVs than small projects. This is not the case with IRR. On the other hand it may be difficult to obtain an IRR, when there are no (high) investment sums made in the first years. While a NPV can always be calculated. In formula:

$$\sum_{t=1}^{n} \frac{(b-c)_t}{(1+IRR)^t} = 0 \text{ ; When } IRR > r : NPV > 0 \qquad [1.2]$$

4.3 Materials and Methods

Brief description of the study area

This research is carried out in two districts: Nyamagabe district in Southern and Gicumbi district in Northern Rwanda. They are located in two somewhat different agro-ecological zones in respectively Crete Congo-Nile Watershed Zone (CNWZ) and Buberuka Highlands Zone (BHLZ). Both zones are characterized by low chemical soil fertility due to important leaching and soil acidity problems. Generally, good soil structure and good to excessive drainage characterize the area. Moderate and steep slopes prevail (25 - 55 %) at an altitude of about 2100 m for CNWZ (South) and 1900-2000 m for BHLZ (North). The annual precipitation is between 1200 and 1400 mm for BHLZ and greater than 1600 mm for CNWZ. Soils are quite deep in both sites with 0.50 to 1.00 m for CNWZ and greater than 1.00 m for BHLZ. The soil texture is characterized by a clay content of about 35-60% for both zones. Major and suitable crops include potatoes, beans, peas, wheat and maize (Fleskens, 2007; MINAGRI, 2008). Both zones have tea plantations and tea factories at which some farmers find part-time jobs. An overview of production of major crops is provided in Table I. It shows, among others, that Irish potatoes are more frequently cultivated in Northern Rwanda (14 percentage of cultivated area) than in Southern area. This study will focus on potatoes, since that crop is most often found on terraces.

Table I. Information on production of major crops in Southern and Northern Rwanda

Crop	Percentage of cultivated area (%)			Average Production (MT)			Average Yield (Kg ha^{-1})	
	South	North	Rwanda	South	North	Rwanda	South	North
Maize	11	9	12	2734	2719	138442	869	900
Wheat	1	7	2	153	6555	44616	300	1800
Beans	18	25	22	5193	8077	194498	988	970
Banana	20	15	21	29923	35193	1373588	5058	7400
Irish Potato	7	14	7	12387	47072	632313	5250	8900
Vegetables	4	4	4	11920	10458	335791	10500	8860
Fruits	2	3	2	6354	9227	196615	10500	10800

Source: MINAGRI (2008)

In both Nyamagabe and Gicumbi Districts, an extensive construction of bench terraces has taken place under GO and NGO support after 1994. Other techniques used for soil erosion control, apart from bench terraces, include: progressive (slowly formed) terraces, hedgerows, agro- forestry, tree planting, mulching, zero grazing, intercropping and water harvesting. As can be expected, there is much variation in use of these techniques by farmers from one district to another and even within each district. Collective actions take place in both districts through farmer organizations and through GO development programmes. Economic options are limited, only some farmers are occasionally employed in the tea plantations as part-time jobs. Existing credit sources are scarce and hence make it difficult for farmers to finance their farming activities despite the fact that this constitutes their major economic activity. Yet, the average cultivable land area per household is very small (about 0.74 ha), which resulted from the fast population growth since the 1940s. Figure 1 shows the maps of the two research locations and their position on the overall map of Rwanda.

Northern Province _Gicumbi District (BHLZ)

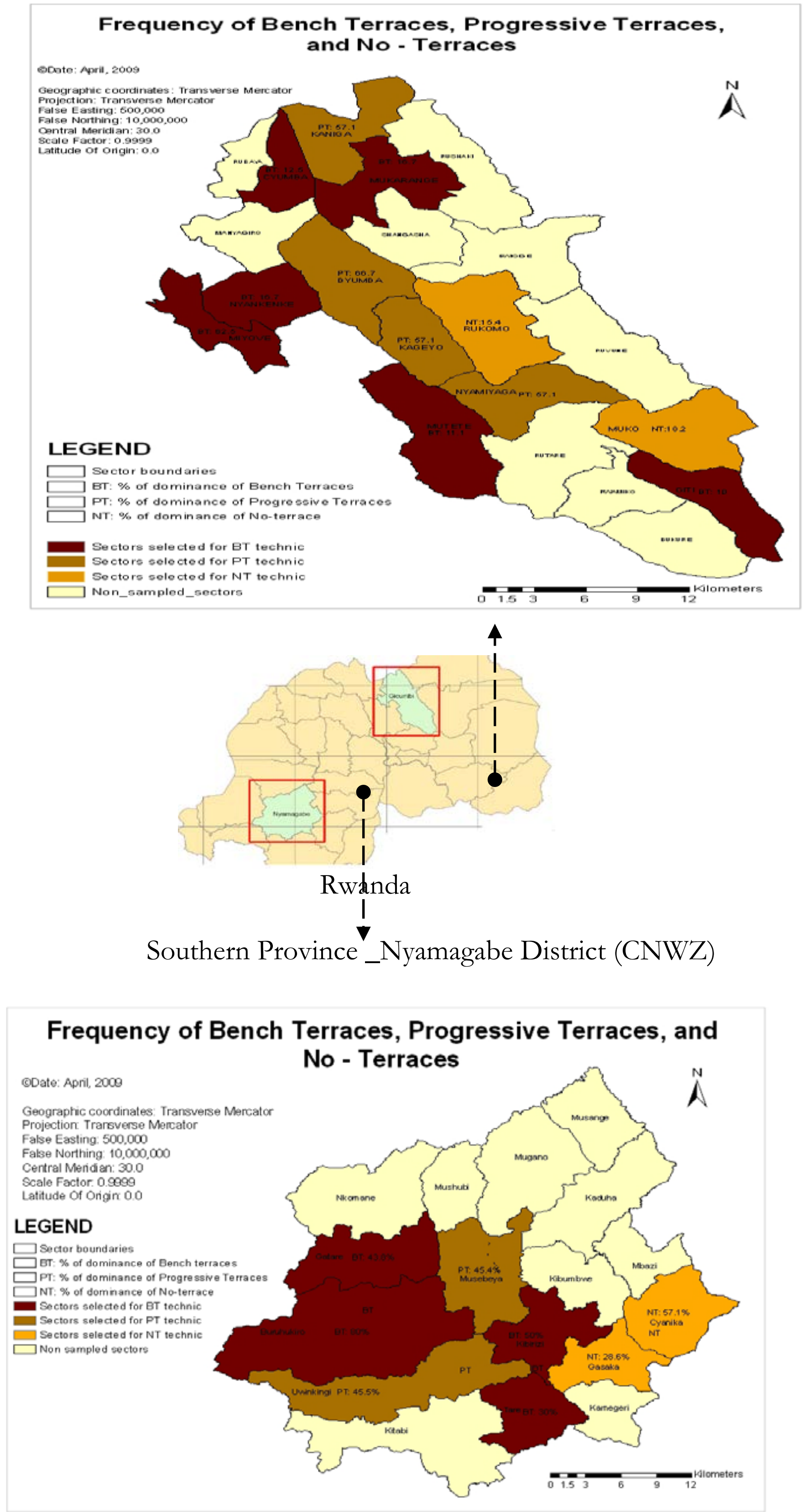

Fig 1. Maps showing the research areas and their location

Soils and soil and water conservation (SWC) measures

Little is known from the literature on SWC in Rwanda about what type of soils are appropriate for what type of SWC technique. To the authors' knowledge, only Habarurema and Steiner (1997) attempted to link soil classification and principle crops using farmers' knowledge in Southern Rwanda. Yet, the need to establish better knowledge of the existing relationships between types of soils and SWC techniques is well felt by farmers, development officials, and researchers. An open window for further investigation by soil scientists and geologists is then available. In this study's perspective, an attempt is made to establish the linkage between soil types and existing SWC techniques in the study area using farmers' classification of soil types. Farmers have considerable knowledge about SWC (Vigiak *et al.*, 2005; Tenge *et al.*, 2007; Habarurema and Steiner, 1997). Two techniques namely bench terracing (BT) and progressive or slowly forming terraces (PT) were considered (See Figure 2).

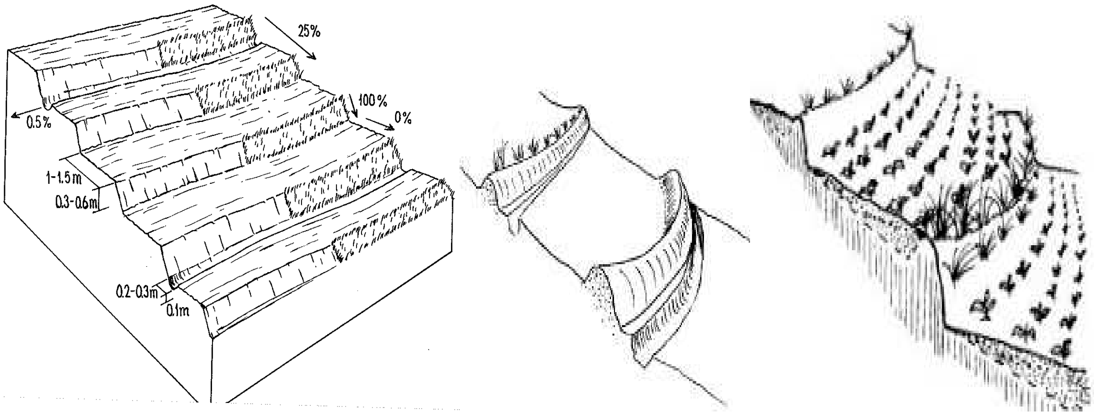

Figure 2: Bench terraces with partly grassed risers and two stadia of progressive terraces (also known as Fanya Juu). Adapted from Liniger, H.P. and Critchley, W. (Eds), 2007.

Data collection and sample design

Information needed for this study has been derived from a survey among 301 randomly selected farmers. This provided also other information for this research project. The sample includes households who received subsidies (about 37 %) and others who did not receive support from SWC programs, in terms of labour for terrace construction (63%). A sub-sample of 101 plots of 82 households was randomly selected (after fulfilling a few criteria, e.g. regarding slope) to analyze the profitability of bench and progressive terraces. This sample is sufficient for financial analysis (Gittinger, 1982; Posthumus and de Graaff, 2005; Tenge, 2005). To measure the yields, we selected plots with potatoes (for two seasons) as this is the crop most often found on the terraces and constitutes a major food and cash crop in the research areas. The 101 plots were selected from areas with a dominant and typical combination of soil, slopes and crops. Plots in sub-catchments within the slope categories of 12 to 25 and 25 to 55 percent were considered for CBA (see Table II).

Table II. Percentage occurrence of slope categories by agro-ecological zone

Agro-Ecological zone	Percentage slope (%)	Percentage of occurrence	Decision
Buberuka Highlands zone (BHLZ-North) (in which Gicumbi falls)	12-25	35-40	Considered
	25-55	60-70	Considered
	55-70	4 -6	Rejected
Crete Congo-Nile Watershed Zone (CNWZ-South) (in which Nyamagabe falls)	12-25	35-55	Considered
	25-55	45-50	Considered
	55-70	0-2	Rejected

In principle CBA compares the 'with' and the 'without' cases and these are respectively represented by plots with terraces and plots with no terraces at all. These terraces are either bench terraces (BT) or slowly forming or progressive terraces (PT). Additionally, most of the bench terraces constructed in the last ten years (1997-2007) were subsidized either by GO or NGOs. This leads to another grouping distinction between subsidized and non subsidized plots with bench terraces. Relying on these criteria four groups can finally be obtained: (1) plots with subsidized bench terraces (SBT) (construction with direct project support for labour), (2) plots with not subsidized bench terraces (NSBT), (3) plots with progressive terraces, as alternative means for soil erosion control (PT) and (4) plots without terraces at all (NT) (Table III). We also compare the first two categories and the third one to investigate the differences.

Data on costs concern all direct costs (inputs) involved in initial investment and for subsequent annual operation, while information on benefits relates to all additional direct earnings (outputs) as a consequence of the investments.

Table 3. Sample plots per agro-ecological zone

Type of plots	SBT	NSBT	PT	NT	Total
North_ BHLZ	12	32	9	9	62
South _ CNWZ	13	10	11	5	39
Total	25	42	20	14	101

1) SBT: Subsidized bench terraces 2) NSBT: Not subsidized bench terraces 3) PT: Progressive terraces 8) NT: Non terraced plots

4.4 Results and Discussion

Awareness of benefits of bench terraces

Awareness about or access to complete information constitutes a key step in the adoption process (Saha *et al.*, 1994; Dimara and Skuras, 2003). Table IV shows (in its lower part) that farmers are aware of benefits of bench terraces, in the sense that they are productive i.e. having a positive effect on production (*85.3 percent*), effective for soil erosion control (*90.6* percent), and that they increase soil fertility (*56.2 percent*). But, evidence in the research area also supports the notion that being 'aware' or having 'complete information' is a necessary but not sufficient precondition to explain adoption of bench terraces. For example, from those who adopted bench terraces, the average time lag for adoption is about 14 years after having become aware of the technique. This lag period represents, among others, the time that farmers took to realize the above benefits of bench terraces or simply the time to real adoption (Lindner *et al*., 1979). The introduction of **Imihigo** program led to large-scale implementation of soil conservation technologies, partly explaining the time lag of 14 years. This supports the idea that farmers can have sufficient information about benefits of a given agricultural technology and decide not to adopt for various reasons. As mentioned, most bench terraces observed in the research areas were promoted by GO and NGO projects, using food or cash for work as incentives. But, not all farmers received these incentives for terrace construction. Table IV also shows the extent to which farmers did eventually take up the enlisted techniques, with or without government and other programme subsidies. None of these techniques is indigenous in the research areas; they have been introduced by development officials and some have been promoted repetitively throughout the history of SWC in Rwanda. Fallowing was the main technique but disappeared due to the ever increasing population, which led to small and fragmented per capita land size and reduced soil fertility: the two major constraints to agricultural development. Apart from bench and progressive terraces farmers use other techniques for soil conservation. For example, the cultivation of crops with good soil cover is higher in the South (80 percent) than in the North (2.4 percent). This concerns among others tea plantations and sweet potatoes. The slightly higher uptake of other soil conservation technologies in the South, such as agroforestry and hedge rows (coupled with trenches) can be explained, all equals, by the fact that the South has received more SWC programs. Since Nyamagabe belongs to the poorest districts, it has received relatively much development assistance.

Table IV. The uptake of soil erosion control technologies and the perceived benefits of bench terraces in the two study areas

Soil erosion control Technique	South (N=136)	North (N=165)	Both study areas (N=301)
	Mean (%)	Mean (%)	Mean (%)
Trenches	34.5	46.7	41.2
Bench terraces	25.0	60	44.2
Progressive terraces	35.3	33.3	34.2
Agro forestry	22.1	15.7	18.6
Intercropping	2.2	1.2	16.6
Cultivation of crops with good soil cover	80.0	2.4	49.8
Hedge rows	18.4	11.5	14.6
Hedge rows coupled with Trenches	36.8	15.2	24.9
Perceived benefits of bench terraces	*N=134*	*N=165*	*N=299*
Productive (Have positive effect on production)	90.3	81.2	85.3
Effective for soil erosion control	96.3	86.1	90.6
Increase soil fertility	55.2	57.0	56.2

Farmers' classification of soil types in relation to soil erosion control

Criteria considered mostly in SWC interventions in Rwanda and when constructing bench terraces include soil erosion risk, slope, and farm size. Less attention is paid to soil properties. But these remain important to determine the physical situation of the fields and respective SWC options (Tenge *et al*., 2007). In view of the above, a question was asked during the survey to indicate the dominant soil type on surveyed plot(s) with bench and/or progressive terraces. Alternative names of soil types were enlisted based on the farmers' classification in Southern Rwanda in Habarurema and Steiner's study (1997).

Their classification is mainly based on farmers' perception with regard to crop suitability (good or bad soils, fertile or infertile soils) and soil productivity. It is clear from Table (V) that **Mugugu** (Ferralsols) (with deep but poor soils and less response to organic fertilizers) is dominant in the Crete Congo- Nile Watershed Zone (CNWZ) (37 percent) while **Urunombe** (Nitosols) (a deep soil with high content of clay and only moderate permeability) is dominant in Buberuka Highland zone (BHLZ). Both bench terraces (33 percent) and progressive terraces (35 percent) are most often constructed on plots with **Urunombe** soils (Nitosols), more or less in line with their occurrence. These soils are often found on sloping land, which can explain the fact that terraces are more often found on **Urunombe** soils than on **Mugugu** soils. Terraces are proportionally less often found on **Mugugu** (Ferralsols) and more sandy soil types, although these have better drainage. To improve their soil fertility, manure is applied on the two dominant soil types: 33 and 18 % on **Urunombe** and **Mugugu** respectively. The soil type of **Urukurwe** (Ferralsols/Alisols) was not identified in any of the sample plots.

Table V. Soil types and Soil erosion control [1)]

Soil type		Description	Agro-Ecological zone		Soil and Water Conservation Techniques		Location of soil types vis-à-vis the hill		
Local name:	FAO- soil classification [2)]	Classification criteria [3)]	CNWZ [4)] *(N=367)*	BHLZ [5)] *(N=540)*	BT [6)]	PT [7)]	Top of hill	Middle of hill	Foot of hill
Urunombe	Nitosols	Medium-high fertility , loamy-clay, moderate permeability	31.6	33.7	32.7	34.7	32.7	36.8	27.9
Mugugu	Ferralsols	Low fertility , loamy, well drained	37.1	0.035	19.37	11.0	11.7	21.7	22.7
Urusenyi	Arenosols	High fertility, sandy, very well drained	13.1	11.8	0.10	13.0	14.2	10.7	12.33
Urubuye	Lixisols	Variable fertility, sandy gravel, very well drained	0.03	18.15	0.07	11.0	12.8	0.097	13.8
Umusenga	Luvisols/ Acrisols	Medium-high fertility , loamy	0.03	0.02	0.014	0.04	0.016	0.016	0.04
Igishonyi	Cambisols	Low-medium fertility, loamy, well drained	0.003	0.016	0.014	0.01	0.008	0.020	0.006
Ikigwagwa	Cambisols	Low fertility, sandy gravel, very well drained	0.003	0.002	0.00	0.00	0.00	0.003	0.006
Urubumba	Alisols /Acrisols	Variable fertility and texture	0.02	0.015	0.003	0.01	0.008	0.017	0.025
Urukurwe	Ferralsols/ Alisols	Low fertility , loamy-clay, insufficient permeability	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: 1) Figures are percentages of plots with respective soil types; 2) Approximate FAO classification by IUSS Working Group WRB(2006); 3) Classification criteria by Habarurema and Steiner (1997); 4) CNWZ: Crete Congo- Nile Watershed Zone; 5) BHLZ: Buberuka High Land Zone; 6) BT: Bench terraces; 7) PT: Progressive terraces.

The effectiveness of bench terraces (BT) established on plots with **Urunombe** soils depends on the depth of the soils and whether the sub-soil properties are (not too) compacted and plastic (what Habarurema and Steiner characterize as **Urunombe rwa rutsima** or **Urunombe rwa bukara**). This property is important especially when constructing the riser ('**umukingo**') of a terrace. Farmers contended that some terraces constructed earlier were destroyed because of the type of soil erosion known as **isuri ya nyamurigita**, that leads to land slides and is more related to the soil permeability property, as depicted in Figure 3. The **Urunombe** soils contain much loam and clay, and could be vulnerable to slides. Pore sizes and their connectivity also determine whether a soil has a low or high permeability. If the soil has a high clay content, small pores and impervious layer underneath, it then has usually a low permeability. There exists a high risk of rotational land sliding as shown in Figure 3, whereby several benches may collapse when there are no proper waterways. How these terraces were constructed, how terraces risers were used and how tillage was practiced explain partly the **nyamurigita** erosion type observed by farmers and that has destroyed their terraces. Most of these terraces were constructed collectively using the food or cash incentives. In such circumstances, there is little chance that technical considerations are the major concern. What matters mostly is the accomplishment of the tasks and getting paid, unless more supervision is available. In such cases, some holes could be created by excess water which may lead to the collapse of the risers of a terrace. The tillage practices also matter and change with technological innovations. The topography of Rwanda does not allow agricultural mechanization in many parts of the country. Tillage is mainly done by the hoe and relies on labour. With bench terracing, tillage is no longer practiced 'downslope' but changes to a 'horizontal and rotating tillage'. Farmers cultivate the layout or the 'bed' of the terrace in horizontal direction and this has to change accordingly to cultural season. The reason is that the slope has been broken down in steps and this allows not only to maintain the top soil with high soil nutrients but also to keep a riser intact. When this riser is well constructed, it allows farmers also to regain the space lost in terrace construction by planting fodder (e.g. *Pennisetum is dominant*) in hedge rows which in turn are used for their livestock or for additional liquidity. Farmers contend that a terrace row of about 15 meter (length) can feed one cow for about three days with an average of three bundles (**imiba**) per day. Thus, bench terracing could help to integrate both agriculture and livestock in the context of limited space for grazing and the zero grazing policy promoted in Rwanda.

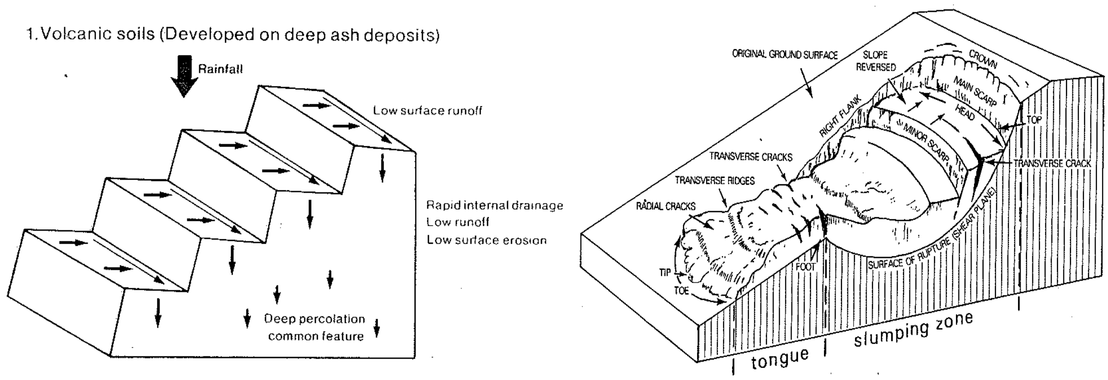

Figure 3. Terraces with good drainage (left) and features of a rotational slide (slump), due to insufficient percolation. Adapted from Carson (1989) and Asch (1980) respectively.

Unlike **Urunombe** soils, the effectiveness of bench terraces established on plots with **Mugugu** soils (Ferralsols) will depend more on soil fertility and less on soil permeability. These soils are characterized by poorer soil fertility due to nutrient depletion leading to increased soil acidity which, in turn, declines yields unless fertilizer is applied (Hartemink and Van Kekem,1994). Despite technical considerations during terrace construction, bench terracing has been claimed to be efficient in conserving soil moisture as result of the levelling of the slope followed by reduced soil run-off (Kannan et al., 2010). Thanks to a relatively good drainage on Mugugu soils, crop performance on terraces can therefore be explained by other factors, including subsequent use of fertilizers, farm management and particularly inherent variation of physical and chemical soil properties (Kannan et al., 2010; Siriri et al., 2005).

Socio-economic characteristics of households and sample plots for financial CBA

In Table VI we present some household and plot level characteristics of the sample plots for the financial CBA. The average age of the head of household (44 years old) suggests that the sample population is generally in the active age. Taking into account that bench terracing is labour intensive, a family with an average of three active persons can construct one hectare of bench terraces within a period of about two years or 667 person days (less than the estimate of 2002 MD ha^{-1} used by World Vision International Rwanda) (Bizoza, 2005). However, farmers usually have less than 1 ha of land and only construct terraces on part of their land. Table VI shows that plot size considered for terraces was in most cases only between 0.16 and 0.32 ha, except for the subsidized bench terrace construction, which showed an average plot size of not less than 0.70 ha (large in relation to available labour). With respect to gender, women headed households seem to go more for PT than BT. A two-sample Wilcoxon rank-sum (Mann-Whitney) test shows that male heads go more for BT than females heads and that the difference is statistically significant at 1 % level (Z=3.5). The test also shows that male heads go less for progressive terraces compared to females (Z =0.039).

Family size of six people is high. It is well known that land tenure in the research area is mostly determined by traditional inheritance. Due to this family size land fragmentation will increase unless the industry and services sectors can accommodate the extra labour and reduce the dependency on the agricultural sector. Interesting to note is that not subsidized BT are found on steeper slopes, more in need of erosion control. The Mann-Whitney test shows indeed that on average NSBT are found on steeper slopes compared to SBT (significant at 5% level, Z=1.97). This measurement of slopes is based on farmer estimates and SBT and NSBT plots are still in the same class of gentle slopes. Not less than 55 % of sample plots fall in the gentle slope category against 20 % in the flat and steep and 5 % in the very steep slope categories. The lower part of Table VI shows the difference in the mean of characteristics for terraces and non-terraced plots and whether these differences are statistically significant or not. Households with subsidised bench terraces have on average a significantly larger family size, plot size, and farm size than those with non terraced plots.

Table VI. Some characteristics of (the heads of) households for sample plots, by type of terracing

Characteristics	Gender (Female=1)	Age	Family size	Family members > 16 years	Mean plot size (ha^{-1})	Mean Slope category[1]	Farm size (ha^{-1})
SBT (*Obs=20*) [2]	0.25	46	6.5	3.4	0.70	1.7	1.4
NSBT (*Obs=42*)	0.33	45	6.2	3.3	0.32	2.1	1.2
PT (*Obs=25*)	0.72	41	6.0	2.9	0.16	2.1	0.56
NT (*Obs=14)*	0.57	42	5.1	2.7	0.17	2.2	0.66
Total sample (*Obs*=101)	0.45	44	6.0	3.2	0.34	2.1	1.02
T-test for significance of mean difference between plot with terraces versus not terraced plots							
SBT versus NT plots		3.7	1.4**	0.6	0.5**	-0.4	0.7*
NSBT versus NT plots		2.7	1.2**	0.6	0.15	-0.07	0.8*
PT versus NT plots		-1	0.9	0.2	-0.04	0.02	-9.2

[1]*Slope categories are: 1= flat, 2= gentle slope, 3=steep, 4 = very steep:*
$* = P \prec 0.05$, $** = P \prec 0.01$
[2] SBT = Subsidized bench terraces; NSBT = Not subsidized bench terraces; PT = Progressive terraces; NT = Non terraced.

Plot level financial CBA of bench and progressive terraces

This sub-section presents an overview of investment costs, yields, operating costs and gross margins used for the financial CBA of bench terraces. Subsidized bench terraces have relatively low costs (to farmers), and lower potato yields (significant at 10 %) and larger fields than those that were not subsidized (Table VII). A possible explanation for the relatively large field sizes could be the fact that some of the plots were constructed under the support of NGOs (e.g. DAP project of World Vision International funded by the USAID and WFP). This support provided short term benefits, leading to rather large terraced plots, some of which were thereafter not fully used and/or others received inappropriate maintenance (like liming and other fertilizers). Inadequate terrace maintenance can lead to an increase of soil acidity and lower crop yields, making it difficult for the investment to pay itself back (Lewis, 1992; Fleskens, 2007). Finally, a lack of access to enough inputs like improved seeds, manure, and inorganic fertilizers will affect the input-output combination and possibly lower the yields until soil fertility is re-established. With regard to progressive terraces, most of them are still in the forming stage making it difficult to determine their overall establishment costs on the basis of the farm survey data. Therefore these investment costs feature not in Table VII, and in the financial costs-benefit analysis on basis of survey data no comparison could be made between BT and PT (Table VIII). Farmers contend that progressive terraces need a period of 5 to 8 years to become level (comparable to benches) which is similar to the 7 years stated by Hudson (1988).

Table VII. Overview of investment costs, revenues, operating costs and gross margins of potato production for the four situations (in Rwandan francs [1]) per ha)

Situations	SBT[4] (n=20)	NSBT[5] (n=42)	BT [2)]	PT (n=25)	PT [2)]	NT[8] (n=14)
	Field Data	Field Data	Standard Estimate	Field data	Standard Estimate	Field Data
Plot size						
Mean (ha)	0.7	0.32		0.16		0.17
Investment (per ha)						
Mandays	858	894	1019	-		none
Costs	366508	339772	10178500		500000	-
Annual gross revenues (per ha)						
Yield (Kg)	6857	9000	15000	5254	15000	5313
Value (Frw)	795262	927043	825000	604198	825000	637619
Annual operating costs (per ha)						
Seed (Kg)	-		2000		2000	
Seeds (Frw)	122605	195458	300000	87604	300000	111503
Fertilizers(Kg)	90	60	300	37	300	10
Fertilizers (Frw)	44339	24479	105000	20411	105000	4365
Manure (kg)	1080	904		813		1281
Manure (Frw)	173620	144800		91315		44203
Pesticide (kg/liters)	10	13	25	7	25	3
Pesticide (Frw)	742	375	45000	607	45000	257
Labour (Mandays)	487	841	470	505	470	572
Labour (Frw)	201853	302316	235000	177088	235000	245427
Total operating costs (per ha)	543159	667428	685000	377025	685000	405755
Gross Margin per ha	252103	259615	140000	227173	140000	231864
Total operating costs, in case opp. costs (50%) of manure & labour [3)]	355423	443870	567500	242824	567500	260940

Gross margin, in case opp.costs (50%) of manure and labour 3)	439840	483173	257500	361375	257500	376679

1) 1USD = 550 Frw in 2008 2) Generated from Fleskens, 2007.
3) Alternative calculation with opportunity costs for manure and labour equal to 50 % of market prices; see below
4) SBT: Subsidized bench terraces 5) NSBT: Not subsidized bench terraces 6) BT: Bench terraces
7) PT: Progressive Terraces 8) NT : Non terraced plots

Table VII shows that the Gross Margins per ha for bench terraces are only slightly higher than for progressive terraces and for not terraced plots, when the input data obtained from the farmers are valued at market prices. Differences in gross margins are not statistically significant. The Gross Margins at this stage do not take into account investment costs, only the annual maintenance costs of the terraces. A more thorough analysis that takes into account these investments costs is conducted in the next part. Differences in revenues from potato yield and expenditure on fertilizers, manure, pesticides and even labour inputs are not in proportion to differences in their quantities due to non-uniform (products and) prices within the research area.

The standard estimates, derived from a national survey (Fleskens, 2007), were used to compare with farmer's estimates. The former show lower GM's per ha, since the level of material inputs is considered much higher. That the standard estimates of labour costs for investment are considerably higher than those obtained from the farm survey, is due to the fact that they used national level wage rates. They considered that operating costs for progressive terraces would be the same as for bench terraces, as they would eventually be similar to bench terraces. We found in the farm survey higher operating costs for bench terraces, possibly partly due to the fact that the progressive terraces were not all fully developed as yet..

Financial CBA is used to examine under which social and economic conditions bench terraces are profitable. Benefits of bench terraces have been perceived by farmers themselves in this research as being very productive, increasing soil fertility and effective for soil erosion (see Table IV). Increased yields on bench terraced plots are found to be a key stimulus for further adoption of bench terraces. But, other variables like soil properties, farm management, crop and rainfall patterns determine the magnitude of this potential and actual increase of yields.

Farmers' estimates of investment and operating costs and potato yields, as shown in Table VII, were analysed to determine at plot level whether bench terraces provide sufficient financial benefits. Subsidized (SBT) and not subsidized bench terraced plots (NSBT) constitute the 'with case' while not terraced plots (NT) under the same physical conditions (of slope, etc.) stand for the 'without case'. It has been assumed that the Gross Margins in the without case will show an annual decline of 3 % as result of continuing soil erosion, assuming that continuous soil mining may lead to abandonment in 30 years. A discount rate of 13 percent and a time period of 20 years were considered. The discount rate was chosen with reference to the interest rate applied by a local bank 'Banque populaire' when farmers request a loan. Results summarized in Table VIII show that SBT are not profitable when market prices are applied. The Net Present Value (NPV) is negative (- 47384 Frw) and the Internal Rate of Return (IRR, of 11%) is lower than the discount rate of 13 %. A possible explanation is that subsidized households have a (too) large plot size but do not fully use it due to lack of labour and liquidity, among others. The NSBT on the other hand seem to be just profitable when considering both the positive NPV (27959 Frw) and the IRR (14%) criteria. We performed the T-test to check whether the average yield of the samples collected in the North is not significantly different from the yield of the samples collected in the South. The analysis shows that the mean difference of potato yields in the two samples in the two regions is not statically different even at 10 % critique level (t = -1.2383). Thus, we confirm that these results are neither distorted by differences in potato yield nor by the fact that more plots with NSBT (about 76 %) are from the samples collected in the North.

But in effect much of the labour used is family labour and manure is from own farms. Markets for labour and manure are also imperfect and formal wage rates and market prices of manure are quite high. Thus, there is a good argument to apply opportunity costs of 50 percent of market value for manure and labour. When this option is considered, SBT are financially viable, with IRR of 25 %. Costs of manure and labour represent important components of total operating costs making the NPV very sensitive to their changes. This explains partly why some farmers are resistant to adopt bench terraces unless assistance is provided from SWC interventions to pay for labour and inputs for maintenance. Positive NPVs and IRRs higher than the discount rate (13 %) are observed for NSBT even with no opportunity cost of labour and manure. It must be admitted that survey results show some variability of conditions between farmers, as shown in Table 6. Posthumus and de Graaff (2005) also assert that whether terracing is financially attractive to a farmer depends to large extent on personal socio-economic circumstances.

Table VIII. Plot level Financial Cost-Benefit Analysis, using farmers' estimates

Category of plots	SBT [1] (N= 20)	NSBT [2](N=42)
Bench terracing investment costs (ha^{-1})	366508	339772
Labour for terracing (MD ha^{-1})	858	894
Gross margin with BT (FRW ha^{-1})	252103	259615
Gross margin without BT (NT case) (FRW ha^{-1})	231864	231864
Annual decline GM as result of erosion, without BT	3 %	3 %
NPV (at 13 % discount rate) (FRW ha^{-1})	- 47384	27959
IRR (%)	11	14
Gross margin with BT (FRW ha^{-1}), using opp. costs.*	439840	483173
GM without BT (NT case) (FRW ha^{-1}), using opp. costs*	376679	376679
Annual decline GM as result of erosion, without BT	3 %	3 %
NPV, opp.costs manure and labour *(FRW ha^{-1})	356517	654553
IRR, opp.costs manure and labour* (%)	25	37

Note: * Opportunity costs for manure and labour equal to 50 % of market prices [1]) Subsidized bench terraces [2]) Not subsidized bench terraces

The information on establishment costs of terraces (including waterways) by farmers is based on rough estimates by farmers themselves and is lower than the official standard estimates. Therefore, we considered also a situation with the standard investment cost for BT and PT to see whether under such investment these techniques are still viable (see Table IX). Without considering any opportunity cost, none of the terraces are viable, although PT show better results. When for the three alternatives opportunity costs (50 % of market value) for manure and labour are considered, PT (IRR of 22 %) and also NSBT seem to be profitable (IRR of 16 %).

Table IX. Plot level Financial Cost-Benefit Analysis, using standard estimates of terrace construction

Category of plots	SBT[3] (N= 20)	NSBT[4] (N=42)	PT[5] (N=25)
Bench terracing investment costs (ha^{-1})	800000	800000	200000
Labour for terracing (MD ha^{-1})	2000 [1)]	2000 [1)]	
Gross margin with BT (FRW ha^{-1})	140000	140000	
Gross margin with PT (FRW ha^{-1})			140000
Gross margin without BT (NT case) (FRW ha^{-1})	231864	231864	231864
Annual decline as result of erosion, without BT	3 %	3 %	3%
NPV (at 13 % discount rate) (FRW ha^{-1})	-511850	-465153	-72863
IRR (%)	2	3	9
Gross margin with BT (FRW ha^{-1}), using opp. Costs[2)]	257500	257500	
GM with PT (FRW ha^{-1}), using opp. Costs [2)]	361375	361375	361375
Annual decline as result of erosion, without BT	3 %	3 %	3%
NPV, opp.costs manure and labour *(FRW ha^{-1})	-91649	161440	191249
IRR, opp.costs manure and labour* (%)	11	16	22

Notes: 1) We used this estimate as this was the standard used by World Vision International for labour payment during the construction of BT in the research area (Bizoza , 2005) 2) Opportunity costs for manure and labour equal to 50 % of market prices 3) Subsidized bench terraces 4) Not subsidized bench terraces 5) Progressive terraces

These results seem to suggest that bench terraced plots can be financially profitable when they are substantially intensified (consistent with Fleskens, 2007). A further analysis is needed to show whether they are also profitable beyond private perspective. The ongoing policy for one cow per family and other interventions aimed at creating enabling conditions for easy access of inputs by farmers are part of the solutions for a sustained profitability of bench terraces. These results suggest that establishing SWC measures should respond not only to the goal of soil erosion control but should also generate better financial gains compared to the situation before the introduction of the technology. In addition to these results, a further analysis to determine costs and benefits of bench terraces at community and national level is recommended. To improve the efficiency of bench terraces in the future, farmers need to be strictly guided in terms of land capability, soil and crop suitability, maintenance and fertility management after BT construction. And in some cases top soil preservation techniques are required, which will mitigate soil disturbance and initial yield reductions. This technical guidance, at construction stage, and improved efficiency of BT will, in turn, increase crop yields, lower maintenance costs and respond, among others, to the overall goal of soil and water conservation in Rwanda. Other studies show that under such conditions bench terracing can be efficient and contribute to sustainable agriculture (Carson, 1989; Tenge, 2005).

4.5 Conclusions

This study investigates under which socio-economic conditions farmers find better returns from cultivating plots with bench terraces compared to those with slowly forming terraces or plots with neither bench nor progressive terraces in Southern and Northern Rwanda. Since soil type constitutes a major criterion for the successful construction of terraces, the study also investigated on which soil types terraces were built, using farmer's classification of soil types. Results showed that both bench terraces (33 percent) and progressive terraces (35 percent) are often established on plots with **Urunombe** soils

(Nitosols with much loam and clay). In some situations, with low permeability these soils are vulnerable to a type of soil erosion known as **isuri ya nyamurigita**, which leads to rotational land slides and the destruction of terraced land. This study recommends a further investigation on soil property variability on plots with bench terraces in order to avoid future terrace construction on less suitable soils.

The national interest in using bench terraces is mostly for soil erosion control. Less attention is paid to its financial profitability for farmers. Although considerable efforts are made to promote terraces, many farmers have not yet introduced this technology in their farming system. This is partly explained by the huge investments that this technology demands. On the other hand farmers themselves indicate that bench terracing provides benefits in terms of increased soil fertility, increased production and effective soil erosion control. We assessed to what extent these perceived benefits are consistent with the actual financial profitability of these terraces with and without the support from SWC projects. The bench terraces built with help of these projects could well have been established on too large (and thus underused) plots and less suitable soils, resulting in less than expected benefits. In these cases sometimes not enough labour is available for weeding, etc

A first analysis of costs and benefits, based on farmers' estimates and market prices shows that Gross Margins on terraced plots are not much higher than those on non-terraced plots and that bench terracing is hardly profitable. However, since use of labour and manure were found to be the main determinants of profitability and these are mostly available on the own farm, the Cost-Benefit Analysis was subsequently also undertaken with opportunity costs for labour and manure (both at 50 % of market prices). This plot level CBA analysis, using both farmers' estimates and official standard figures, showed that bench terraces in that case are profitable. The implication is that bench terracing can be a financially viable option for SWC, when either costs of labour and manure can be reduced or more intensive use is made of the terraces, with higher potato yields. That farmers perceive the terraces as profitable, could also show that they value the opportunity costs of their own labour below the market value. For this study, the profitability of bench terraces was assessed and based on farmers' estimates, obtained in only 1 year. Subsequent studies should also consider other crops and collect data over more years to assess costs and benefits of bench and progressive terraces. Finally, a broader analysis is required to determine all possible effects and impacts of bench terraces at community and national level.

CHAPTER 5

INSTITUTIONS AND THE ADOPTION OF TECHNOLOGIES: BENCH TERRACES IN RWANDA[4]

5. 1 Introduction and motivation

The alarm of soil erosion and declining soil fertility in Africa is still buzzing. Who is going to switch it off? How and when? These remain important policy and research questions about land degradation and conservation in Sub-Saharan Africa. Soil and water conservation has been an integral part of agricultural development in Africa since the early twentieth century. Successive governments and development organizations invested heavily in different measures to reduce erosion and to promote sustainable agriculture since colonial Africa. However, soil erosion problems persist. Bench or stone terracing is one of the soil and water conservation (SWC) techniques promoted in East Africa (e.g. Ethiopia, Kenya, Tanzania, Rwanda) since the 1960s. Its adoption and continued use by small-scale farmers has been criticized invariably by scientists.

Previous studies identify factors that drive adoption of agricultural technologies. These vary from bio-physical, socioeconomic, and institutional factors (Rezvanfar *et al.*, 2009; Graaff *et al.*, 2008). However, much remains ill-understood. Why? In the past, focus has been more on geographical conditions, people's economic and demographic characteristics, than on the role of local institutions. The current trend in the literature recognizes the specific role of local institutions in land conservation and in natural resource management more generally (e.g. Sanginga *et al.,* 2010; Bouma and Bulte , 2008; Isham, 2002).

The main objective of this paper is to analyse the impact of various (local) institutions on the adoption of bench terraces in Northern and Southern Rwanda. The paper responds to one question in particular: are institutional or geographical variables more relevant to explaining the adoption of terraces? This study fits into the wider literature (mainly cross-country) on institutions versus geography/endowments as determinants of development.

The paper's outcomes are relevant for policy and research options in land conservation. Measuring the impact of local institutions on the adoption of terraces allows the Rwandan government to tailor further investments in land conservation to existing social and institutional arrangements at the local level. Relevant institutions are empowered to ensure the long-term sustainability of established SWC measures by both governmental and non-government organizations (NGOs). One of the controversies centres on the issue that previous attempts in soil and water conservation by these organizations were top-down with only partial success in many developing countries, including Rwanda (e.g. Graaff, 1996).

The results contribute also to the increasing scientific debate on the substitutability or complementarity of local versus formal institutions (e.g. Ahlerup *et al.*, 2009; Bigsten *et*

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al., 2002). It appears in the Rwandan context that both government (formal) and local people (informal) based institutions are functional in rural development. Soil and water conservation serves for a fertile ground where both types of institutions coexist. The measure of the impact of local institutions presented in this paper is based on investments in bench terraces of which both public and private benefits evolve. Results show that local institutions affect the adoption of bench terraces and that they can serve for alternative resources for farming implements in poor-based economies such as Rwanda.

The paper assesses the impact of social capital variables and tenure security (among others) on the adoption of bench and progressive terraces. Similar to earlier studies of technology adoption, the findings show that some geographical and household-level variables will explain the adoption of bench and progressive terraces. Importantly, social capital based on trust and co-operation in collective action matters in the adoption of bench terraces but not of progressive terraces. These findings echo the literature that states that soil and water conservation is driven by local institutions. Unlike earlier work on the adoption of SWC measures, tenure security does not explain the adoption of bench and progressive terraces in rural Rwanda.

There is a lengthy academic debate on tenure security and land investments in Africa. Deininger and Feder (2009) summarize some of the discussion: tenure security lowers spending to protect (land) rights, increases levels of investments (as the future fruits of current investments are likely to appeal to investors) and, possibly, empowers women. However, these effects are less certain in situations of better functioning land markets (including rental rights) and improved access to credit (due to collateral).

Many African states have attempted to ensure long-term land rights through formalization (Barrows and Roth, 1990). The formalization of land rights is not a panacea. Sometimes it is not necessary as customary land-right systems are functioning well (André and Platteau, 1998), and due to the considerable costs associated with a full-fledged titling scheme (e.g. definition, measurement, and enforcement). A recent study by Saint-Macary *et al.* (2010) in Vietnam also concludes that 'the issuance of land titles is a necessary but not a sufficient prerequisite to encouraging the adoption of soil conservation practices'. This brings us to the distribution of socio-economic power, governance and the nature of interventions (Deininger and Feder, 2009). In relation to governance issues, one needs to know whether there is impartial access to the judicial system in order to guarantee land rights. If not, land rights may only exist on paper. Hence, we should look beyond tenure rights to understand investments in land quality.

Turning to the local level, do other dimensions of the institutional framework matter? The literature suggests that social capital is relevant. Social capital translates into reduced transaction costs (precluding the necessity to write contracts that capture all contingencies), facilitates the exchange of information, and enhances trust. In addition, social capital enables communities to overcome social dilemmas, which is particularly relevant in the context of sizeable investments such as the construction of bench terraces to counter erosion. Bouma *et al.* (2008) show that social capital based on trust and co-operation enabled community resource management in India. On the other hand, social capital does allow for different interpretations due to the variability of cultures that endorse different mechanisms and expressions of social capital (Krishina, 2004).

Social capital is important in Rwandan rural society. This paper distinguishes between different types of social capital. It examines cognitive (or soft) social capital and structural (or hard) social capital, and their effects on technology adoption. There is a growing body of literature that associates social capital with improved adoption of new technologies (e.g. for an overview, see Landry *et al.*, 2002; for applications to Africa

Boahene *et al.*, 1999; Bandiera and Rasul, 2002; Isham, 2002). A recent study by Ahlerup *et al.* (2009) suggests that social capital and formal institutions are each other's substitutes in development, so that social capital is especially important for the poorest countries where formal institutions are of relatively low quality – Sub-Saharan African springs to mind.

Microanalyses of the role of social capital in Africa confirm its important economic role, and its significance when formal institutions are weak (e.g. Narayan and Pritchett, 1999; Bigsten *et al.,* 2004, Fafchamps and Minten, 2002). For instance, a positive experience in Machako, Kenya, shows how social capital serves private assets by which farmers could access resources and services that were formerly subjected to high transaction costs in soil conservation (Nyangena, 2008). In addition to tenure security and social capital, this paper explores other plot-, farm-, and household-level determinants of soil conservation.

Traditionally, large-scale investments in soil and water conservation are associated with high investment costs and external effects, which would explain the perceived need of the state and NGOs to intervene. Indeed, historically it appears as if large-scale terracing requires a certain level of top-down planning. This intervention approach invested more in labour pooling for soil conservation and less in social and human capital creation. As Pretty and Ward (2001) put it: 'international agencies, governments, banks, and NGOs must invest more in social and human capital creation, and to ensure the transition is made from dependence to interdependence, which in turn helps to build assets'. Clearly, past interventions were involved less in strengthening social arrangements between farmers in order for them to address soil erosion problems by their own institutions. This explains, at least partially, why past interventions in soil and water conservation failed (Hurni *et al.,* 2008; Graaff, 1996).

Section 2 presents an overview of bench terraces in Rwanda. Section 3 describes the data and the empirical strategy used to analyse the impact of local institutions on the adoption of terraces in Section 4. Section 5 ends with a discussion of the major findings and conclusions.

5.2 Bench terraces in Rwanda

Bench terracing were introduced in Rwanda in the 1970s. Other SWC techniques had been established earlier, such as hedgerows and progressive terraces (trenches coupled with hedges). Both bench and progressive terraces received a lot of attention from different development interventions in agriculture. Establishing these terrace structures requires a few topographical criteria, including angle of slope. A bench terrace is constructed by breaking up the slope (with a gradient of 25–55%) into different segments in order to maintain the top soils, which are rich in nutrients, and to keep the riser of the terrace intact. Progressive terraces result from tillage practices combined with the planting of hedgerows over a certain period of time, and they are recommended on plots that are less steep (12–25% gradient). These two techniques differ partly in terms of effectiveness to counter run-off, soil erosion control, capacity to conserve water, and the time needed to change soil properties (Kannan et al. 2010). Mountainous areas similar to most parts of Rwanda are very sensitive to rain erosion. In the short term, bench terraces are deemed to be more effective technically at soil erosion control than progressive ones (Posthumus and Stroosnijder, 2010). The layout or 'bed' of progressive terraces takes longer to form (about seven years); this explains their technical effectiveness in the long run (Hudson,1988). Nevertheless, bench terraces call for substantial material and labour inputs in the early, installation stage compared to progressive terraces (Hurni *et al.*, 2008).

The history of bench terraces in Rwanda is linked to state policies and regulations and to interventions by NGOs (Bizoza and Hebinck, 2010). The approach used to promote these terraces has shifted over time from top down to somewhat participatory. Various development policies promoted by the current government, such as the 'performance contracts' (known as *Imihigo*), collective communal work (*Umuganda*) and *Agasozi Ndatwa* (literally meaning a 'model hill'), entail certain aspects of community-based development, promotion of farmers' associations and co-operatives, and a self-reliance mentality towards rural development. In the case of soil and water conservation, these policies are geared primarily towards collective awareness and soil erosion control. At the same time farmers operate in small-scale associations and co-operatives from which different forms of social capital originate (e.g. trust, co-operation, and mutual assistance or reciprocity).

Despite theoretical claims that social capital matters for investments in SWC measures, few empirical case-studies exist for Eastern Africa (e.g. Nyangena, 2008; Isham, 2002). Moreover, Graaff *et al.* (2008) present a summary of factors affecting adoption and continued use of SWC measures (including terraces) from recent studies in five developing countries: Tanzania, Ethiopia, Peru, Bolivia, and Mali. Institutional variables considered include land tenure, extension contracts, programme participation, and group participation. These factors measure 'structural' social capital. Trust, as part of 'cognitive' social capital, is not considered. To the author's knowledge, no study has related empirically these forms of social capital to the adoption of SWC measures in Rwanda. This paper investigates their impact on the adoption of bench and progressive terraces in the North and Southern provinces of Rwanda.

Apart from government interventions, NGOs such as World Vision International played prominent roles in the construction of terraces in the period after the 1994 war and genocide in Rwanda (Bizoza *et al.*, 2007). Bench terraces were constructed in some areas using food support from the USAID. The food-for-work programmes have been contested in the literature for nurturing a dependency mentality, among other effects. Material incentives and the commoditization of labour may have created paternalistic behaviour and possibly distorted the real sense of existing local institutions such as mutual support.

Despite efforts and progress made, the job of soil erosion control continues. The 2008 National Agriculture Survey (NAS) showed that 62.2 % of the cultivable area (an estimate of 1 280 750 ha) is protected by anti-erosive measures. Furthermore, 4.2 % of the protected area is provided by bench (radical) terraces compared to 69.2 % by anti-erosion ditches of which progressive terraces are formed. Kannan et al. (2010) indicate that 93.2% of the total potentially cultivable area is positioned on hillsides under rain-fed conditions and, thus, would be sensitive to soil erosion unless measures are taken. With bench terraces being encouraged by policy in the last three decades, why is progress so slow?

From private perspective, bench terracing is not obviously an optimal soil conservation option (Hurni *et al.,* 2008, Saint-Macary *et al.*, 2010). As indicated above, bench terracing leads to higher investments, which take longer for farmers to pay back unless they are coupled with additional, improved agricultural practices (Posthumus and Graaff, 2005; Bizoza and Graaff, 2010). Since the top soils of these terraces have been disturbed from an early stage, it has resulted in low soil fertility and high inputs. Typically, in places like Rwanda where per capita land holdings are very small (less than 1 ha), farmers hesitate easily to invest in a such technology. Unless measures to use terraced plots effectively are provided by govermental organizations and NGOs, farmers are rational not to construct terraces on small plots, much of which they depend on for their livelihoods. Indeed, this case-study proves that some smallholders abandon their terraced plots or fail to use them productively (approximately 10%). Results from Bizoza and Graaff (2010) in the same research area show that bench terraces built with help of support projects could well have been established on plots that are too large (and thus underused) and on less suitable soils, resulting in less than expected benefits. Equally, the same NAS (2008) shows that 10% of farm land is uncultivated. This is noteworthy in a land-scarce country such as Rwanda.

Therefore, the government intends to further promote terracing through different public and private initiatives. Hence, it is important to learn more about the characteristics of the adopters and the role of local institutions in fostering adoption. For this purpose, a distinction is made here between bench and progressive terraces to guide policy to tailor future interventions by responding to which types of terrace are demanded by which categories of farmers in rural Rwanda.

5. 3 Data and empirical strategy

The aim here is to analyse the impact of various local institutions on the adoption of bench terraces in rural Rwanda. The hypothesis will be maintained that dimensions of social capital matter in the adoption of bench terraces. For this purpose, household-level data were collected among 301 households who also provided plot-level information on 907 plots located in the North and Southern provinces in Rwanda. Specifically, the research is carried out in areas (sectors) that cover major parts of the Gicumbi (Northern) and Nyamagabe (Southern) districts of Rwanda.

The data collected allow for testing the impact of variables on the adoption of terraces, vector grouped as follows: plot controls, farm and household-level characteristics, tenure security, sector-level aggregates, and social capital. Plot-level controls (X) include slope (dummies), plot size, origin (inherited or otherwise), and the walking distance from home to the plot. Farm and household-level factors (W) comprise altitude, farm size, erosion potential, and socio-demographic characteristics of the heads of sample households (gender, age, family size, formal and informal education). The sector-level aggregates (Z) consist of support programme (World Vision) and average income.

Social capital (SC) and tenure security (TS) are the institutional variables of interest. As Krishna (2004) points out, 'it is not easy to observe social capital; people carry it inside of their heads', making it difficult to measure and to associate it with economic outcomes such as investments in bench terraces. Trust and membership of an organization are two indicators often used for empirical measurement of social capital (Glaeser *et al.,* 2002; Krishina, 2004). Accordingly, social capital can be divided into two categories: cognitive social capital (SC_1), manifested by trust and participation in collective labour teams, and structural social capital (SC_2), observed through membership of voluntary organization(s).

In order to measure trust, the survey asked the following question: Do you trust any of the following categories of people: household members, members of the extended family, neighbours, people in the community, local leaders, and leaders of their respective churches? Trust was coded on a four-point scale, ranging from 1 ('not at all') to 4 ('very much').

Table 1
Summary statistics of variables fitted in the analysis of adoption of bench and progressive terraces

Explanatory Variables	Description	Obs.	Mean	SD
Institutional Factors (**SC**)				
Trust the community	Average score of community trust (1= not all and 4= very much).	301	3.42	0.38
Collective action	Equals 1 if the plot has been terraced through collective action.	907	0.06	0.24
Association membership	Equals 1 if a farmer is a member of the association and 0, if otherwise	300	0.33	0.47
Tenure security (**TS**)	Equals 1 if a farmer perceive land secured in the future and 0, if otherwise	301	0.83	0.37
Plot controls (**X**)				
Steep Slope	Equals 1 if the slope of the plot (s) is steep and 0, if otherwise	907	0.21	0.41
Gentle Slope	Equals 1 if the slope of the plot (s) is gentle and 0, if otherwise	907	0.55	0.49
Plot size	Size of the plot in are (1 are = 0.01 hectare)	907	35.94	107.8
Inheritance	Equals 1 if a farmer inherited the land and 0, if accessed the land by other means	299	0.62	0.48
Distance	Distance from home to the plot in minutes	907	12.92	17.05
Farm and Household characteristics (**W**)				
Altitude (m absl)	Average altitude of the sub-catchment / Village	301	2103	163.34
Farm size	Total farm sizes in Ares (1 are = 0.01 hectare)	301	107.4	255.46
High erosion potential	Equals 1 if the household is located in an area with high risks of erosion.	301	0.14	0.35
Moderate erosion potential	Equals 1 if the household is located in an area with moderate risks of erosion.	301	0.32	0.46
Female head	Equals 1 if female and 0, if otherwise	301	0.50	0.50
Age	Number of years old of the head of household	299	43.37	13.59
Family size	Total family members	301	5.73	2.07
Formal education	Years of formal education completed	301	2.75	3.18
Informal education	Equals 1 if a farmer has received agricultural training/field visit/ extension meeting and 0 if otherwise.	301	0.31	0.46
Total Livestock Unit (TLU)	Cattle size (=0.8), pigs (=0.2) , sheep and goat (=0.1)	301	1.25	1.19
Sector-level variables (**Z**)				
Programme support	Equals 1 if a farmer is from a sector supported by World Vision International.	301	0.41	0.49
Average Sector-level Income	Average of income per sector	301	68640	45575
District	Equals 1 if the plot (family) is located in the North and 0, if the Southern region.	301	0.55	0.49
Depedent Variables				
Adoption of bench terraces (BTA)	Equals 1 if a given plot (family) has bench terraces and 0 if otherwise.	907	0.32	0.47
Adoption of progressive terraces (PTA)	Equals 1 if a given plot (family) has progressive terraces and 0 if otherwise.	907	0.28	0.45

The survey questionnaire asked also whether terraces had been constructed through collective labour, in order to measure its effect on the adoption of terraces. Labour is a major component of investments in bench terraces; and social capital is considered important in playing an economic role in labour markets (Knight and Yueh, 2008). Collective action aimed at pooling labour to construct terraces at the individual plot level is regarded to be an alternative asset for farmers in addressing labour constraints for soil conservation and probably with regard to other farming constraints as well (Meinzen-

Dick, 2009). Hence, a positive and conducive effect of collective action on investment in terraces is expected here.

Membership of associations is an important local institution expected to have a positive effect on the adoption of bench terraces. Farmers join their associations for a variety of reasons, such as mutual support (reciprocity), access to input credit, training, and sharing of agricultural implements. Therefore, farmers who are members of associations are more likely to share experiences and pool resources, which, in turn, might allow them to adopt terraces on their private lands. The government also encourages membership of farmers' co-operatives. In addition, due to the increasing cognizance of the role of women in rural social and economic life, women-based organizations are taken into account. Hence, the survey asked whether the respondent was a member of any of these voluntary organizations (Yes/No).

Tenure security (TS) is another institutional dimension expected to influence the decision to invest (or not) in terraces (Deininger and Jin, 2006). Land titling is still going on in Rwanda. The survey included a question about perceived tenure security, whether the respondent(s) thought that he/she would continue to use the land during their lifetime. Table 1 describes other independent and dependent variables identified in the model.

Data have been analysed at plot level. It is possible for a given household (i) to have more than one plot (k) with variant physical characteristics and household-specific variables. Probit ML estimator has been applied (Wooldridge, 2002), with robust standard errors clustered at household level in order to estimate our adoption model specified as Equ.1. A district dummy (Z) was included in variables to control for potential heterogeneity between the two districts in the study area. The dependent variable Y stands for either bench terrace adoption (BTA) or progressive terrace adoption (PTA).

$$Y_{ik} = \alpha + \beta_1 SC_{1i} + \beta_2 SC_{2i} + \beta_3 TS_i + \gamma_1 X_k + \gamma_2 W_i + \gamma_3 Z_c + \varepsilon_{ik} \qquad (1)$$

Where i indexes the household, k stands for the plot, while c denotes sector-level variables. Y_{ik} stands for either BTA or PTA with Y_{ik} =1 if adoption occurs or Y_{ik} =0 in the case of non-adoption. SC_{1i}, SC_{2i}, TS_i, X_k, W_i and Z_c are the vectors of observable explanatory factors as described above, while β_i is a vector of estimated coefficients. Finally, ε_{ik} is the error term, which is assumed to be random.

Endogeneity of regressors is not of concern for the geographical variables since they are given. However, some of the institutional measures, namely trust, tenure security (TS) and association membership, are potentially endogenous. The standard Durbin-Wu-Hausman (DWH) test was applied to investigate whether exogenous variation in these factors could be identified (Cameron and Trivedi, 2009). The difficulty in the use of instrumental variable approaches when establishing the causal effects of social capital is finding relevant and valid instruments (Knight and Yueh, 2008). This is the case for the 'trust' variable. Alternatively, average scores of community trust were used, which are less likely to be correlated with individual residuals.[5] The DWH test for endogeneity of tenure security (TS) and association membership resulted in a strong acceptance of the null

[5] Another option is to compute trust and association membership scores at household level using factor analysis (Narayam Pritchett, 1999; Nyangena, 2008). These scores were loaded and tested in the analysis. Only the trust index has both positive and significant associations with BTA. However, reported results are those with an average score for community trust.

hypothesis that TS (F(1,300)=0.697208; (p=0.4044)) and association membership (F(1,300)=0.700373; (p=0.4033) are both exogenous. Therefore, the assumed endogeneity of tenure security and association membership variables is no longer a problem. Hence, they can be identified in the regression analysis.

5.4 Empirical results

Two equations have been considered: one for bench terrace adoption and one for the adoption of progressive terraces. The purpose is to examine what factors determine adoption of bench and progressive terraces, with a focus on local institutions. Obtained coefficients are based on robust and clustered standard errors at household level. The marginal effects of the explanatory variables are computed at their sample means.

Table 2 presents results from the analysis of BTA. The results show that, among the three sector-level variables (Z), the coefficients of sector-average income and district dummy suggest positive impacts on the adoption of bench terraces (both significant at the 1% level). The inference is that higher income farmers are more likely to adopt bench terraces compared to those with a low income. The dummy coefficient indicates that farmers in the Northern province have adopted more bench terraces compared to those in the Southern province. This outcome is in line with expectations. Bench terracing started in the Northern province before being introduced in the Southern province, which provides a partial explaination of the difference. Surprisingly, World Vision's support programme, although positive, proved to have no significant association with the adoption of bench terraces. This is difficult to explain. A possible answer can be found in the higher number of samples used in the analysis from random sectors that did not receive much support from World Vision for bench terrace construction (about 65%).

Table2
Probit regression of adoption of bench and progressive terraces with robust standard errors (clustered at household level)

Variable	Bench terrace adoption (BTA)		Progressive terrace adoption (PTA)	
	Coefficient (Robust Std. Dev)	Marginal effect	Coefficient (Robust Std. Dev)	Marginal effect
Institutional factors (SC)				
Trust	0.408 (0.132)***	0.141	-0.163 (0.122)	-0.052
Association membership	-0.182 (0.126)	-0.061	0.010 (0.121)	0.003
Collective action	2.136 (0.297)***	0.678	-0.069 (0.232)	-0.021
Tenure security (TS)	0.104 (0.137)	0.035	0.118 (0.148)	0.037
Plot Controls (X)				
Steep Slope	0.489 (0.169)***	0.178	-0.254 (0.143)*	-0.078
Gentle Slope	0.339 (0.133)**	0.115	-0.055 (0.118)	-0.017
Plot size (Log)	0.157 (0.052)***	0.054	0.164 (0.048)***	0.053
Inheritance	-0.223 (0.104)**	-0.077	0.105 (0.097)	0.033
Distance	-0.021 0.004)***	-0.007	-0.009 (0.003)***	0.003
Farm and household level variables (W)				
Altitude (m absl)	0.002 (0.000)***	0.0007	0.002 (0.0003)***	0.0007
Farm size	-0.104 (0.068)	-0.036	-0.095 (0.074)	-0.031
Higher erosion	-0.648 (0.151)***	-0.193	0.193 (0.147)	0.065
Moderate erosion	-0170 (0.120)	-0.057	0.189 (0.122)	0.062
Female head	-0.534 (0.121)	-0.052	0.171 (0.115)	0.0554
Age	-0.013 (0.023)	-0.004	-0.008 (0.025)	-0.003
Age (squared)	0.0001 (0.000)	0.00002	0.00007(0.000)	0.00002
Formal education	0.001 (0.019)	-0.0004	-0.008 (0.017)	-0.002
Informal education	0.315 (0.133)**	0.111	0.181 (0.121)	0.059
Family size	0.058 (0.034)*	0.020	-0.028 (0.028)	-0.008

Total Livestock Unit (TLU)	0.013 (0.056)	0.004	-0.084 (0.054)	-0.027
Sector-level variables (Z)				
Programme Support	0.105 (0.129)	0.036	0.292 (0.132)**	0.095
Average sector-level income	4.07E-06 (1.24E-06)***	1.42E-06	-2.07E-06 (1.37E-06)	-6.70E-07
District	0.577 (0.138)***	0.190	0.807(0.141)***	0.244
Constant	-6.630 (1.163)***		-5.287 (0.994)***	
Regression diagnostics				
Log Likelihood	-430.754		-485.904	
Chi-square (23)	193.49		116.04	
Probability > Chi-square	0.0000		0.000	
Pseudo *R*-square	0.2494		0.1007	
Predicted Probability at mean	0.294		0.258	
Sample size (*n*)	906		906	

$^*P < 0.1$, $^{**}P < 0.05$, and $^{***}P < 0.01$.

Some farm and household-level variables (W) correlate with the adoption of bench terraces at different critical levels: altitude (m absl), high potential erosion, informal education, and family size. Farmers with plots located in mountainous catchment areas with high potential erosion are more likely to adopt bench terraces for easy cultivation of steep plots and to protect the soil from run-off than farmers in the lowlands (significant at the 1% level).

Formal education is specified in most of literature as conducive to adopting conservation agriculture (e.g. Graaff *et al.,* 2008; Diagne and Demont, 2007; Dimara and Skuras, 2003; Mbaga-Semgalawe and Folmer, 2000). However, this does not apply to most cases (Knowler and Bradshaw, 2007). A possible explanation lies in the assumption that number of years of education correlates strongly with decision to adopt. In small-scale and traditional farming practices such as in Rwanda, it is difficult to believe that formal education plays a major role (Welch, 1978). For instance, it is debatable whether a sample farmer with an average age of 43 and with 3 years of primary education will rely on the knowledge obtained back at primary school after 34 years (assuming he or she started primary education at 6 years old). Instead, informal education explains most of the adoption of conservation technologies such as bench terraces (significant at the 5% level). Therefore, it is more likely that farmers adopt because of the experiences they share with neighbours, training they receive, and their contacts with extension officials.

Plot characteristics such as gradient level and plot size, mode of land access, and the distance from home to the plot matter in a farmer's decision to invest in soil and water conservation. Bench terraces are established on steeper plots (gradient levels of 25–55%). While progressive terraces are supposed to be established on plots with slope percentages of 12–25%, in this research both slope categories (steep and gentle) are correlated positively with the adoption of bench terraces (significant at the 5% level). To some extent, this reflects insufficient technical consideration at an early stage of terrace construction. The estimated positive coefficient of plot size has an important effect on soil and water conservation investments (significant at the 5% level). Plot size together with steepness of the plot may affect the width and the length of a terrace, and thus the choice of whether or not to adopt, all else being equal.

Distance from home to the plot discourages investment in soil conservation (significant at the 1% level). Clay *et al.* (1998) found a similar result in their Rwandan study. The more remote a given plot from the homestead, the greater the transactions costs expected, especially when farmers rely on head transport for their household residues and other inputs. The security issue seems relevant in this situation. The correlation between tenure security and distance from homestead to the plot was tested and it was found negative and not statistically significant (even at the 15% level).

From the above, it does appear that farmers respond to economic incentives. In spite of the evidence that the cost–benefit ratio for investing in bench terraces is not very favourable, farmers do seem to focus their terracing efforts on the plots they use most intensively: plots close to the house and plots with the highest labour intensity.[6] Results from the T-test confirm that terraced plots receive more labour inputs compared to unterraced or progressively terraced ones ($t = -6.28$; significant at the 1% level). This is consistent with Bizoza and Graaff (2010), who show that not all terraced plots are cultivated and that labour costs constitute a major part of the operating costs in rural Rwanda. Therefore, comparison of bench terraces with other soil conservation techniques will show that better consideration of labour requirements is critical for cultivation, terrace construction costs, and maintenance (Dehn, 1995).

Customary land tenure is dominant in Rwanda. Often, family inheritance systems determine how people access land in Rwanda and elsewhere in Africa (André and Platteau, 1998). The majority of the samples in this research accessed their land through inheritance (62%) and few purchased (26%). Equally, the 2008 National Agricultural Survey reports that 45.5% accessed their land through inheritance compared to 24.7% who bought their lands. Our empirical evidence indicates that the more the land (plot) is inherited, the lower the adoption probability of bench terraces (significant at the 5% level). Meanwhile, vast claims have been made in the literature for the need for individualization and registration of plots in Rwanda. The government has instigated a process of land registration and the issuance of formal land rights. However, this may not be necessary to induce investments in land conservation. There is little empirical evidence from similar contexts in Africa and other developing countries to support the position that formal land titling or traditional rights have increased investment in agriculture (Barrows and Roth, 1990 Saint-Macary *et al.*, 2010). Hence, whether formal or traditional land rights are conducive to the adoption of soil conservation measures should be considered context-specific and remains open to empirical debate in Rwanda.

Next up are the effects of local institutions on bench terrace adoption. The analysis shows a positive association between some of the measures of social capital and an increased probability to invest in bench terraces. Trust as part of cognitive social capital (SC_1) is highly conducive to investments in bench terracing (significant at the 1% level). This is consistent with Bouma *et al.* (2008), who also maintained that farmers in villages with high levels of trust are likely to contribute willingly to community resource management. Terracing leads to site as well as downstream effects that require farmers to act collectively. Efforts by one farmer to invest in bench terraces may be undermined if other farmers up- or downstream do not adopt (Nkonya *et al.* 2008). Thus calling for collective adoption. In such a situation, social capital will ease co-operation among people for them to work collectively. One believes that others will reciprocate and also contribute to the public good. The research also shows that collective action in the form of labour pooling, another measure of SC_1, has a positive association with the adoption of bench terraces (significant at the 1% level). This had been expected. As noted earlier, building a terrace is a big job, best done in a group. Living in a community where such forms of co-operation occur helps in the construction of terraces, a task much more difficult for individuals to perform on their own.

[6] Labour allocation per plot (excluding labour for terrace construction) was rejected in the estimation as it was found to correlate positively and strongly with BTA (at the 1% level).

Surprisingly, the effect of structural social capital (SC_2), represented here by membership of farmers' associations, is zero. This outcome stands in contrast to other empirical findings from previous studies where membership of associations has positive and significant associations with investment in soil conservation (e.g. Nyangena, 2008, Rezvanfar *et al.* 2009). Farmers receive services from their organizations, including information about the need for terracing. Typically, these organizations are multipurpose in nature. It is, therefore, possible for someone to be a member of an organization without necessarily having to adopt bench terraces, *ceteris paribus*.

Tenure security (TS) does not explain BTA. The results contrast with earlier studies that maintain that tenure security favours long-term investments in SWC (Nyangena, 2008; Shiferaw and Holden, 2001; Gebremedhin and Switon, 2003). Two offsetting effects might explain this outcome: (i) farmers can invest in soil conservation measures when they feel they have tenure security, or (ii) they can invest in order to achieve tenure security for their landholdings. There are no formal titles in Rwanda although the land titling process is ongoing. Nevertheless, about 80% of the survey respondents feel they have tenure security – these are people farming plots that they inherited from their fathers compared to farmers who have purchased plots (holding deeds) or who have accessed plots by other means. In addition, the need to secure land is justified mainly when risk of appropriation is significant or when better land markets exist. None of these two cases are evident in the study area, which explains the low impact of tenure security in the adoption of bench terraces in Northern and Southern Rwanda. In conclusion, farmers need to feel their land is secured when they have made substantial investments; however, this requires additional measures such as credit subsidies to improve the capacity to invest in terraces.

Overall, results from the analysis mirror the growing academic debate that local institutions matter in the adoption of soil and water conservation. However, not every dimension of the institutional framework (as specified) is found to be important in the Rwandan case. Trust and collective action are instrumental in explaining terrace adoption. There is no empirical proof that the adoption of bench terraces can be explained through association membership or tenure security justify, although this is relation is assumed important in policy and other researches.

Columns 3 and 4 of Table 2 present results from the analysis of progressive terrace adoption (PTA). Only six of the variables used are instrumental in explaining the adoption of progressive terraces. Sector-level estimates (Z) of programme support (by World Vision) and the district dummy suggest increased probability of PTA (significant at the 5% and 1% levels, respectively). Average sector income is not significant, which suggests that farmers in areas with higher than average incomes are likely to prefer BTA over PTA, under *ceteris paribus* conditions. Contrary to the outcomes of the analysis of BTA, programme support does explain PTA (significant at the 5% level). A possible reason could be World Vision International Rwanda's recent development strategy to promote progressive terraces after recognizing that some of constructed bench terraces were too expensive for farmers to use.

Among the farm and household variables (W), distance from home to the plot and plot altitude (m absl) correlate with PTA. These variables are estimated with their expected signs and the implications of results is the same as for BTA. Among the plot-level variables, only plot size is instrumental in explaining PTA (significant at the 1% level). Therefore, plot size matters when considering investing in either BTA or PTA.

Of the institutional variables, neither trust, collective action, association membership or tenure security explain PTA. Since progressive terraces are build slowly because of tillage and use of hedges, reciprocity in pooling labour or sharing agricultural implements is less common compared to bench terracing. Trust lubricates co-operation in situations where reciprocity in sharing labour and implements prevails (Pretty and Haward, 2001). Similar to the results in the analysis of BTA, there is no empirical evidence that association membership and land tenure security encourage PTA.

In summary, the empirical results reflect that social arrangements are necessary in order to establish bench terraces but not for progressive terraces. The marginal effects (at sample mean) of trust ($dy/dx = 0.141$) and collective action ($dy/dx = 0.678$) suggest social capital an alternative asset(s) to be taken into consideration when investing in bench terraces in Rwanda. That is, farmers in areas endowed with high levels of social capital are likely to adopt bench terraces when the government and NGOs decrease or stop their interventions (Bouma *et al.*, 2008, Ahelerup *et al.*, 2009).

5.5 Discussion and conclusions

In this study, the role of local institutions, among other factors, is considered in the adoption of bench terraces in rural Rwanda. The results of the analysis sustain the ongoing discourse that social capital maters for soil and water conservation. Soft institutional factors – trust and the ability to co-operate in collective action – affect the adoption of bench terraces more than 'hard' ones – association membership. None of the local institution variables explain adoption of progressive terraces. Furthermore, perceived tenure security does not explain adoption of either bench terraces or progressive terraces. This may be due to the peculiar nature of the case study, where informal (customary) tenure rights still play an important part.

Another significant insight from the analysis is that farmers do want to have terraces and allocate their best plots for this purpose – plots that are large in size, close to the house, and intensively cropped. On the other hand, it is revealed that some farmers are unable to secure complementary materials and labour inputs. Consequently, some fail to use effectively their terraced plots. In addition to the promotion of terracing, interventions by NGOs and policy-makers should also focus on the sociocultural settings in the early stage of soil and water conservation measures. In poverty-based economies such as Rwanda, local institutions can supplement government and NGO investments in soil and water conservation. Farmers can construct terraces themselves through their own local institutions. This does not imply total withdrawal of state involvement in soil conservation, but the need for the state to co-operate with local institutions in a variety of innovative ways to sustain complementarity (Meinzen–Dick 2009). Therefore, government and NGOs need to allocate further investments in the consecutive use of established terraces than in the construction of new ones. New thinking rather than reviving old institutions and traditions is needed to develop forms of social organization that are structurally suited for soil and water conservation at the local level and for the overall development of agriculture (Pretty and Ward, 2001).

Results show also that bench terraces were constructed on plots with either gentle or steeper slopes. Farmers need more training before they embark upon the terracing process to ensure technical efficiency and sustainability of established terraces. Finally, the above findings confirm the hypothesis that local institutions play an important role in the adoption of bench terraces in rural Rwanda. More research is needed to advise how these social arrangements can play better their roles and into the extent to which they can supplement or even substitute direct interventions by NGOs and the state in soil and water conservation on private land in Rwanda.

Returning to the research results, some general lessons can be drawn about the role of institutions on the adoption of new agricultural technologies. *First*, the effect of tenure security on a farmer's decision to invest in agricultural technologies should be analysed with caution, especially in developing countries similar to Rwanda. Land tenure security does depend also on the interaction with other factors such as land governance, credits and markets in agriculture (Meinzen-Dick, 2009). Moreover, measuring the extent to which farmers feel they have tenure security, often with a single binary indicator, seems oversimplified to accommodate confounding effects of such factors on land tenure in microanalysis. This explains partly why in most studies, including this case-study, the effect of land tenure on the adoption of technology is found to be insignificant (for a review, see Feder *et al.*, 1985; Gebremedhin and Switon, 2003; Knowler and Bradshaw, 2007; de Graaff *et al.*, 2008). Especially in Africa, costly soil conservation measures such as bench terraces involve public interventions that, in many cases, may be calculated into private decision-making to adopt such soil conservation measures. Therefore, proper analysis of the role of tenure security in adoption of soil conservation is expected at government or institutional level rather than micro-economic analysis (Meinzen-Dick, 2009); such analysis lies beyond the scope of this paper.

Second, there is a general claim in recent literature that membership of farmers' organizations is conducive to natural resource management (Sidibé, 2005; Nyangena 2008; Rezvanfar *et al.*, 2009). However, membership can also predict a range of social capital measures (Glaeser *et al.,* 2002). It is assumed invariably that farmers may gain through membership many kinds of support from government and NGOs, such as credit, training, sharing of agricultural implements, including labour pooling to erect soil conservation structures (Sidibé, 2005; Nyangena, 2008). Moreover, farmers' organizations provide an intermediary layer of institutional arrangements through which extension and other development agents operate. Therefore, better analysis of membership needs to open up this 'black box' and investigate the extent to which farmers gain (or lose) assumed benefits from membership. This will explain much better the role of membership of farmers' organizations in soil conservation and rural development in general.

CHAPTER 6

THREE-STAGE ANALYSIS OF ADOPTION OF SOIL AND WATER CONSERVATION IN THE HIGHLANDS OF RWANDA[7]

6.1 Introduction

The knowledge of why some farmers will or will not adopt new technologies is fundamental, and has been analysed by many economists (Ervin and Ervin, 1982; Feder *et al.*,1985, Knowler and Bradshaw, 2007). It is well documented in the literature that technology adoption by farmers requires a multistage process of decision-making, rather than the single, dichotomous decision to adopt or not (Dimara and Skuras, 2003; Gebremedhin and Swinton, 2003). The explanation is that some of the deciding factors are dynamic and require, therefore, a shift from static to a dynamic observation (Dimara and Skuras, 2003; Feder *et al.*, 1985). Typically, less attention is paid to why some of the adopted technologies are discontinued by farmers after their decision to adopt and programme support stops.

A variety of soil and water conservation (SWC) measures have been introduced in developing countries, including Rwanda, to counter soil erosion and to increase agricultural production. Early efforts focused mostly on soil erosion control rather than on integrating such efforts with programmes aimed at increasing agricultural production. Winters *et al.* (2004) argue that, in a situation where the location of terraces is determined by an outside expert rather than the farmers themselves, development officials may construct terraces on areas where they are effective for soil erosion control, but not where they are conducive to agricultural production. Accordingly, terracing that does not fit the farmers' capacities to invest in additional inputs will have possibly no effect on production. This may explain why some SWC techniques established in many parts of Rwanda (and elsewhere) were underused, abandoned, and eventually disappeared (Olson, 1994; Bizoza and Hebinck, 2010).

If so, the explanation is not that farmers are not cognisant of soil erosion problems and their effects on production (Clay and Lewis,1990). Instead, the limited ability to secure complementary inputs required by the technology could be part of the story. This inability restrains farmers from achieving goals of soil erosion control, poverty reduction, and increased agricultural production (Gebremedhin and Swinton, 2003). The latter goal is a key incentive to increase land conservation by farmers. Farmers are sufficiently rational to continue using as well as adding aspects of technologies that have proven to be profitable, all else being equal.

Terraces (both bench and progressive) are the most important SWC techniques in the recent history of soil conservation in Rwanda. Terracing entails substantial construction costs in terms of labour and complementary inputs, especially at the early stage (Winter-Nelson and Amegbeto, 1998). Thus, few farmers have the means to construct terraces, unless support is provided by SWC programmes. During the period after 1994 and prior to 2006, farmers received extensive support from the government and NGOs via food and cash for work incentives to construct terraces on public and private lands in many parts of Rwanda (Bizoza *et al.*,2007; MINECOFIN, 2009). Later, the government introduced and reinforced institutions drawn from Rwandan traditional society, such as

[7] This chapter will be reworked into a journal article

public community work (known as *Umuganda*) and the performance contract (known as *Imihigo*). These institutions encourage collective action, sometimes used for terrace construction, and self-reliance in soil and water conservation and other development activities. The leading assumption in some of these interventions is that farmers will maintain and continue using established terrace structures beyond programme support. However, experiences from other African countries, including Kenya, Tanzania, and Ethiopia, suggest this should not be taken for granted (Tenge *et al*, 2004; Pretty and Shah, 1997; Shiferaw and Holden, 1998).

Both past and ongoing efforts in soil conservation have led to a mixed situation where some farmers have some terraced plots that are well maintained and used, some farmers with terraced plots that are not maintained and underused, and some farmers with plots that are not terraced (although the plots are appropriate for terrace construction). This situation can be explained partly by a lack of sufficient transitional measures such as maintenance funds (Bouma *et al.*, 2007) that would allow farmers to better maintain and continue using terraces already established under various SWC interventions. If strategies to facilitate farmers continued use of existing and newly constructed terraces are not in place, effects linked to soil properties such as increased soil acidity, nutrient depletion and decreased crop yields are likely to be worse than before (Lewis, 1992; Clay and Lewis, 1990). It constitutes a challenge for future generations of soil conservation technologies in particular and agriculture development in Rwanda in general.

This overview emphasizes the importance of studying technology adoption or disadoption as a dynamic process in the sense of early and late adopters or non-adopters. The present study contributes to this 'dynamism' of technology adoption or disadoption in agriculture by looking at the ability of small-scale farmers to invest in existing and new terraces in Rwanda. Having such information helps us to promote conservation agriculture in Rwanda, tailored to the social and economic conditions of farmers (Knowler and Bradshaw, 2007). This paper addresses the question of whether farmers are willing to adopt new terraces in the future beyond current adoption and SWC programme interventions. The aim of this paper is to assess which factors affect farmers' current and future decisions about adoption of bench terraces, focusing on their capacity to invest in inputs in Northern and Southern Rwanda. The capacity to invest has been overlooked by some SWC interventions; however, it is an important long-term investment principle (Gebremedhin and Swinton, 2003).

The rest of the paper is organized as follows. Section 2 will present some recent researches on agricultural technology adoption and subsequent decisions. Section 3 will produce a model for analysing current and future adoption decisions of farmers about their capacity to invest in bench terraces. Section 4 will describe the survey data used for the empirical analysis while Section 5 will present and discuss key results. Finally, Section 6 will present the concluding remarks with some policy actions.

6.2 Recent research on the adoption and continued use of agricultural technology

Many recent studies have considered two-stage adoption decision processes rather than simple dichotomous adoption decisions. For example, Dimara and Skuras (2003) analysed the awareness and adoption decisions of technology as a two-stage partially observable process. Adegbola and Gardebroek (2007) investigated modification of improved maize storage facilities by farmers to adapt them to their circumstances in Southern Benin as a second stage to adoption. Neill and Lee (2001) explain disadoption after adoption of maize–mucuna in Northern Honduras. Gebremedhin and Swinton (2003) considered the adoption of and long-term investments in stone terraces in the Tigray region of Ethiopia. Amsalu and de Graaff (2007) also studied the adoption and continued use of stone terraces, in the Beressa watershed located in the central highlands of Ethiopia.

These recent studies and others observe the continuity of technology among (often early) adopters in terms of the second stage of the adoption model. The continuity reflects the intensity and the capacity to maintain and use the adopted technology. However, continuity of the technology can also be observed among late adopters, because when a new technology is introduced within the community it is either adopted or dis-adopted over time. Again, large-scale innovations such as soil and water conservation will have downstream effects and can lead to collective adoption. Therefore, continued use and future adoption can be observed among both early adopters and non-adopters (Rogers, 1962).

Future adoption can be evaluated in terms of the perceived benefits of a technology among non-adopters. New adopters form part of the explanation of the continuity of technology and they should, therefore, be included in the model of technology adoption in agriculture. Thus, the continued use of bench terraces contains both current and potential adopters, who may learn from the early adopters within their respective communities that bench terraces can be beneficial assets (Rogers, 1962; Adegbola and Gardebroek, 2007). The learning period involves many issues. It may involve a search for further information on the costs and benefits of a given technique, a trial period, modification, valuation of the impact of adoption on economic activity, rejection or acceptance of the technology (Rogers, 1962; Winters *et al.* 2004; Dimara and Skuras, 2003; Adegbola and Gardebroek, 2007). In this study, current and future adoption decisions of bench terraces are bridged by farmers' abilities to invest in existing and new bench terraces.

6.3 A model for analysing initial and future adoption of bench terraces

In this paper, the adoption of bench terraces is regarded as a three-stage decision-making process. Stage one comprises the analysis of current or initial adoption decisions of bench terraces, while stage two assesses farmers' ability to continue the use of terraces. Per capita household income is used as a proxy for farmers' capacity to invest. Stage three analyses future adoption proxied by farmers' willingness to uptake more terraces. The analytical method starts from adoption rather than from awareness (Dimara and Skuras, 2003; Saha *et al.*, 1994). It is assumed that farmers are already aware of adoption, a stage which has been well documented in the academic literature. A possible explanation could be that the government of Rwanda cautioned farmers against use terraces and other SWC measures through various nationwide campaigns since 1970s (Clay and Lewis, 1990). Assuming that farmers are aware of bench terraces established in many parts of the study area, omitting the awareness stage will not cause significant specification bias (Dimara and Skuras, 2003). Figure 1 examines the relationship between adoption decisions, farmers' capacity to invest and future adoption of bench terraces in the highlands of Rwanda.

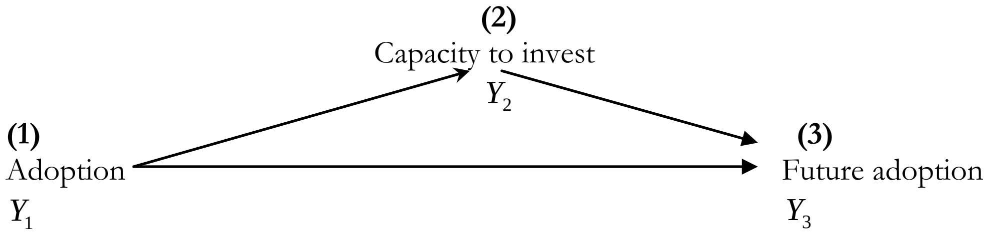


Figure1. Path diagram of recursive causality between current adoption, farmers' capacity to invest and future adoption of soil and water conservation

Assuming that appropriate land for terracing is available ($Lt \succ 0$; with 25–55% gradient), adoption decision Y_1 is observed among early adopters also willing (or not) to construct new terraces. Farmers' capacity to invest is assessed after some farmers have constructed terraces on some of their plots, this can possibly affect their income and hence the capacity to further invest in terraces, *ceteris paribus*. In order to test the effect of adoption (Y_1) on farmers' capacity to invest (Y_2), the relationship between (1) and (2) will be examined. In addition, early adopters are likely to take up more terraces in the future than non-adopters due to relatively better advantages (e.g. more information about terraces, terracing skills from 'learning by doing'). This hypothesis will be validated through the assessment the relationship between (1) and (3) – that is, by calculating the effect of current adoption (Y_1) on future adoption (Y_3).

Farmers' decisions to develop more (new) terraces will depend, among others, on expected future benefits and on their capacity to invest in operating inputs (Shiferaw *et al.*, 2009). Therefore, the capacity to invest in operating inputs (Y_2) is viewed here as a driving factor determining future adoption. It serves as an alternative proxy for the outcome of the valuation process that precedes the willingness for future adoption of bench terraces. The potential effect of farmer's capacity to invest on future adoption is taken into account when assessing the impact of (Y_2) on (Y_3) – that is, the relationship between (2) and (3).

Most of the SWC measures in the study area are promoted by government programmes and NGO's concerned for the threat of erosion (Graaff *et al.*, 2008). Adoption as currently observed is to some extent induced by incentives provided by these programmes (Bunch, 1999). It becomes important to know whether farmers are willing to implement new bench terraces beyond such interventions, which depends on the capacity to invest in long-term soil conservation. This ability determines whether already established terraces can be intensified and can be of continued use. The decision about actual or future investment in terraces also depends on other social, economic, and institutional factors sometimes overlooked by SWC programmes. Accordingly, these factors are hypothesized to affect future adoption of bench terraces. They are expected to affect per capita family income (a proxy for farmers' capacity to invest), which, in turn, is expected to affect the decision for future adoption. For this purpose, a system of three equations is devised. The main hypothesis is tested for future adoption of bench terraces to be conditional upon both current adoption and farmers' ability to invest in complementary inputs for sustained soil conservation and agricultural production.

We assume two latent response variables for the current and future adoption equations (Y^*_1 and Y_3^*) and a continuous dependent variable for the capacity to invest in terraces (Y_2). Each latent variable is a function of some explanatory variables, and the equations contain some common variables in addition to some that appear only in one of the equations. Assuming a linear specification of the latent variables, the three equations are defined as:

$$Y_1^* = x'_{1i}\beta_1 + u_{1i} \quad (1)$$

$$Y_2 = x'_{2i}\beta_2 + \delta_1 Y_1 + u_{2i} \quad (2)$$

$$Y^*_3 = x'_{3i}\beta_3 + \delta_2 Y_1 + \alpha Y_2 + u_{3i} \quad (3)$$

Where Y^*_i and Y_2 represent the dependent variables; β stands for a vector of parameters to be estimated; x_i is a vector of conditioning variables for the i^{th} individual household; u_i captures all unobservable factors that affect the dependent variables, assumed to be normally distributed ($u_i \sim N(0,\sigma^2)$). The potential effect of early adoption on farmers' capacity to invest and on future adoption is assessed in the model by estimating the partial slope coefficients of dummy adoption δ_1 and δ_2, respectively. The effect of farmers' capacity to invest on future adoption is taken into account as when computing the slope coefficient α in the recursive equation (3). The latent variables Y_1^* and Y_3^* are not observed. What is observed though are the respective qualitative variables indicating the presence or not of current (Y_1) and future adoption (Y_3).

$$Y_1 = 1 \text{ if } Y_1^* > 0 \text{; 0 otherwise} \quad (4)$$
$$Y_3 = 1 \text{ if } Y_3^* > 0 \text{; 0 otherwise}$$

The above equations reveal a special case of the multiple equation model comprising both limited Y_i^* and continuous Y_2 dependent variables. At the same time, these two variables appear at the right hand side of equation (3) as endogenous dummy and continuous regressors. The logic of this model follows the recursive structure (Maddala, 1980:110). Thus, the model is more likely to fall in the category of recursive multiple equation probit models than linear simultaneous equations (Nelson and Olson, 1978; Wilde, 2000). The reason for this is that the path of causality for the three variables is fully recursive (see Figure 1) (Maddala, 1983:108). Evaluation of this model is not a straightforward procedure considering the measured dependent variables represent a mixture of two different distributions. As a result, assessing the whole system (equations 1 to 3) becomes difficult or can mislead predictions. We suggest three exit options to evaluate this model.

Option 1. Here, each equation of the system is estimated individually with an appropriate technique. The probit ML method is applied to estimate current adoption (Y_1^*), while OLS estimates are obtained from equation (2), farmers' capacity to invest (Y_2). A two-stage method is applied to estimate future adoption (Y_3^*). First stage coefficient estimates are obtained from equations (1) and (2), which, in turn, are used to construct predicted values for their counterpart endogenous variables in equation(3). This leads to a single equation and the structural coefficient estimates are obtained in the second stage by the probit ML method (Nelson and Olson, 1978). Also Nelson and Olson contend that the standard errors reported in the second stage are not correct but may still guide as approximations. To obtain adjusted standard errors, it becomes necessary to apply the bootstrapping option built into the Stata programme (Cameron and Trivedi , 2009).

Option 2. Under this option, current (Y_1^*) and future adoption ($Y^*{}_3$) are estimated as a bivariate probit regression. Since some farmers who adopted (or not) can still be willing to construct more (or new) terraces on their unterraced plots, there is greater likelihood that the disturbance terms of these two equations are correlated: Var(u_{1i})=Var(u_{3i})=1, and i is the individual index (Neill and Lee, 2001; Wilde, 2000). However, Maddala (1983: 123) affirms that, if u_{1i} and u_{3i} are not independent, the probit ML method will not give consistent estimates of the parameters for equation (3) due to the presence of the dummy endogenous adoption Y_1. Thus, following Maddala's suggestion, equation (3) is respecified to become the next equation (5) in order to obtain consistent probit ML estimates. The effect of Y_2 can still be captured among conditional variables x'_{3i} as a continuous regressor. The model is reduced to a recursive system of two adoption equations ((1) and (5)). This new model can, therefore, be estimated by the two-stage method. First, probit ML estimates $\hat{\beta}_1$ of β_1 are obtained from equation (1) and $\Phi(x_{1i}'\hat{\beta}_1)$ is substituted for $\tilde{Y}_1$ in equation (5).

$$Y_1^* = x'_{1i}\beta_1 + u_{1i}$$
$$Y^*{}_3 = X'_{3i}\beta_3 + \delta_2\tilde{Y}_1 + u_{3i} \quad (5)$$

Where

$$\tilde{Y}_1 = \text{Probl } (Y_1^* > 0)$$

If predicting joint probability of (Y_1, Y_3) is assumed, this yields to four possible cases of joint probability:
$P(Y_1 = 1, Y_3 = 1)$, $P(Y_1 = 1, Y_3 = 0)$, $P(Y_1 = 0, Y_3 = 1)$, $P(Y_1 = 0, Y_3 = 0)$.

The case of $P(Y_1 = 1, Y_3 = 1)$ is possible if farmer i is currently an adopter and is willing to construct more terraces. $P(Y_1 = 0, Y_3 = 0)$ applies when farmer i is not currently an adopter and is not willing to adopt terraces in the future, or do not have appropriate land available for more terracing, or he/she is unwilling to adopt at all.

The joint probability of $P(Y_1 = 0, Y_3 = 1)$ implies that farmer i is not currently an adopter but is willing to construct new terraces, all else being equal. As indicated above, farmers in this category have been ignored in some of past studies on adoption and continued use of agricultural technology. Future adoption and, hence, continuity of the same agricultural technology can be explained by both current adopters and non-adopters willing to construct new terraces. The log likelihood function to be maximized is given by Maddala (1983:123) as

$$L(\delta_2, \beta_1, \beta_3) = \Pi P_{11}^{Y1Y3} P_{10}^{Y1(1-Y3)} P_{01}^{(1-Y1)Y3} P_{00}^{(1-Y1)(1-Y3)} \quad (6)$$

Option 3. The third option at hand is to estimate the system as a whole – Eq.(1) to Eq.(3) – using the classical two-stage least square (2SLS) technique. In the above two options, the probit ML, OLS and the two-step probit are applied to individual equations of the system and they ignore simultaneity (Nelson and Olson, 1978). The 2SLS is usually used in the estimation of the linear simultaneous equations. Since the system is recursive and has some endogenous explanatory variables with no restriction on parameters, the 2SLS method can be applied to estimate the whole system equation. The choice of 2SLS recalls the notion of identification of multiple equation probit models with an endogenous dummy variable. In this case, Wilde (2000:312) asserts that 'no exclusion restrictions for exogenous variables are needed if there is sufficient variation in the data'. For Maddala (1983:120), the condition for identification holds if at least one conditional variable in one equation is not included in the other equation(s). For this model, the identification condition holds as each equation of the system has at least one variable that does not appear in the other equations. Another advantage of 2SLS is that it can be used for the instrumental variable (IV) estimation of an overidentified model or different variants of the GMM (Cameron and Trivedi, 2009).

6.4 Data and model variables

The data used for this study were obtained from a random sample of 301 households in Northern and Southern Rwanda between March and May 2009. The survey respondents are from two agroecological zones namely Buberuka Highland zone (BHLZ) in Northern province and Congo-Crete Nil watershed zone (CNWZ) in Southern Rwanda. These two zones have a similar topography and received relatively more SWC interventions due to high erosion risk compared to other zones in Rwanda.

For sampling purposes, the study area was divided into three topographic areas, based on the dominance of gradient percentages: 12–25%, 25–55% and 55–70% slopes. The first category is appropriate for progressive terraces while the second one is appropriate for bench terraces. The third category was rejected as it is meant for use other than agricultural production, such as tree plantation. Subsequently, the GIS mapping tool was used to map the dominance of soil conservation techniques, namely bench and progressive terraces, in 20 sectors – a sector is an administrative unit greater than a village. Of these sectors, 10 represent areas/sub-catchments where bench terraces are dominant, 6 areas are dominated by progressive terraces, while 4 sectors characterize sub-catchments with fewer or even no terraces at all.

The data set contains information collected at sector, household, and plot levels. At the sector level, information was obtained from observation, interviews with key informants such as village leaders, in addition to other measured variables such as altitude and programme support. Data on household and plot characteristics were obtained from face-to-face interviews with 301 heads of households. The number of respondents selected is proportional to the size of each sector, and on average 15 households were interviewed per sector. Given this paper's focus on long-term investments of bench terraces, only geophysical characteristics for unterraced plots of both adopters and non-adopters of bench terraces are used in the analysis. The explanatory variables are specified with reference to previous studies on technology adoption (e.g. Feder *et al.*, 1985; Knowler and Bradshaw, 2007; Dimara and Skuras, 2003; Gebremedhin and Swinton, 2003). The variables include socioeconomic characteristics of sample farmers, geophysical characteristics of unterraced plots, institution-related factors, and farmers' perceptions of the benefits of bench terracing. Descriptions and measurements of these variables are summarized in the Table 1.A.

Table 1.A
Description and definition of model variables

Exp. Variables	Mean	Std.Dev.	Description
(i) Socioeconomic Characteristics			
Female head	0.50	0.50	Equals 1 if female and 0, otherwise.
Age of head	43.37	13.59	Number of years old of the head of household.
Family size	5.73	2.07	Total family members.
Available labour	2.99	1.36	Family members with $\geq$16 Years old.
Farm size	107.4	255.46	Total farm sizes in Ares (1 are = 0.01 hectare).
Head's formal education	2.75	3.18	Years of formal education completed.
Head's informal education	0.31	0.46	Equals 1 if a farmer received agricultural training/field visit/ extension meeting and 0; if otherwise.
Total livestock units	1.25	1.19	Cattle size (=0.8), pigs (=0.2) , sheep and goat (=0.1)
(ii) Geophysical characteristics			
Gentle slope	0.55	0.49	Equals 1 if gentle slope and 0, otherwise.
Steep slope	0.21	0.41	Equals 1 if steep slope and 0, otherwise.
Very steep slope	0.05	0.23	Equals 1 if very steep slope and 0, otherwise.
High erosion	0.17	0.37	Equals 1 if high potential erosion risks and 0, otherwise.
Moderate erosion	0.33	0.47	Equals 1 if moderate potential erosion risks and 0, otherwise.
Altitude (m absl)	2088	156.3	Meters above see level captured with GPS at sector level.
Distance	13.13	17.14	Distance from home to the plot in walking minutes.
(iii) Institutional factors			
Collective action	0.06	0.24	Equals 1 if the plot has been bench terraced through collective action by farmers themselves (mutual assistance).
Land tenure security	0.84	0.37	Equals 1 if a farmer feels lifetime land secured her and 0, if otherwise.
Association membership	0.36	0.48	Equals 1 if a farmer is a member of the association or a farmer cooperative and 0 if otherwise.
Programme support	0.43	0.49	Equals 1 if a farmer/plot is from a sector supported by World Vision International and 0 if otherwise.
(iv) Perception related factors			
Perceive benefits of bench terraces	0.54	0.50	Equals 1 if a farmer perceive benefits of bench terraces and 0 if otherwise.
Dependent / Endogenous variables			
Current adoption of bench terraces	0.60	0.49	Equals 1 if a given household has adopted bench terraces and 0, if otherwise. Households with at least one row or one plot with bench terraces are considered as adopters.
Future adoption of bench terraces	0.68	0.46	Equals 1 if a farmer is willing to construct more or new bench terraces and, 0 if otherwise.
Family income (agriculture)	137354	210075	Annual household income from agriculture for the period (2008B and 2009 A). This is used as a proxy for farmer's capacity to invest in bench terraces.

The figures in Table 1.B represent Z values and respective significance levels of mean difference for socioeconomic characteristics between the three categories of sample households: early adopters of bench terraces (60%), late adopters (19%), and non-adopters (21%). The characteristics that distinguish early adopters from late and non-adopters are family size, labour availability, total livestock units, and household income (significant at the 1%, 5%, and 10% levels). These are some of the key socioeconomic characteristics hypothesized in the literature to affect the adoption (or not) of conservation agriculture. However, these characteristics do not provide universal evidence for the influences on the decision to adopt conservation agriculture (Knowler and Bradshaw, 2007).

Table1.B
Mann-Whitney test for significance of mean difference between early, late, and non-adopters

Sub-samples	Early adopters (N=182)	Late adopters (N=57)	Non-adopters (N=62)
	Early versus Late adopters	Late versus Non-adopters	Early versus Non-adopters
Variable name	[Z] Prob > [Z]	[Z] Prob > [Z]	[Z] Prob > [Z]
Age of head	2.77***	2.23**	0.03
Family size	2.58***	0.29	2.53***
Available labour	3.01***	2.23**	2.12**
Farm size	1.43	1.41	3.10***
Head's formal Education	0.37	2.71*	2.85***
Head's informal education	0.96	1.77*	3.02***
Total livestock unit s	2.22**	0.63	1.74*
Family income (agriculture)	4.58***	1.43	3.25***
Off-farm income	1.8*	2.43**	1.14

* $P \prec 0.1$, ** $P \prec 0.05$, *** $P \prec 0.01$

6.5 Empirical results and discussion

This section will evaluate the above-presented system of three equations: current adoption (Eq.(1)), farmers' capacity to invest (Eq.(2)), and future adoption (Eq.(3)). The analysis focuses on future adoption of bench terraces conditional upon prior adoption and farmers' capacity to invest in complementary inputs. The results contain three alternative sets of values corresponding with the application of the three above-mentioned estimation options. Table 2.1 presents coefficient values and their significance levels of the current adoption using probit ML, bivariate probit ML, and classic 2SLS. Table 2.2 summarizes OLS, two-step probit ML, and 2SLS values of Eq.(2) and Eq.(3). Because Eq.(3) has been respecified under option (2), results from Eq. (5) are contained in column 4 of the Table 2.2. Observed changes of coefficient values – magnitude, expected signs, and statistical significance levels – as a result of altering the estimation approach of the three equations are also reported for comparison and discussion.

6.5.1 Adoption of bench terraces

Stage one explores which socioeconomic, geophysical, and institutional factors affect current adoption of bench terraces. Ten of the nineteen identified parameters enter significantly at the 1%, 5%, and 10% levels. Positive coefficients of some of these parameters (head's informal education, gentle slope, steep slope, altitude, plot size, collective action) are associated with increased probability of adoption. Estimated coefficients with a negative sign are related with decreasing probability of adoption (female head, high erosion potential, moderate erosion potential, and distance from home to the plot). Apart from high and moderate erosion potentials, other statistically significant variables show anticipated effects on the adoption of bench terraces in the highlands of Rwanda.

The negative sign of female head is expected and suggests that female-headed households are less likely to choose bench terraces compared to male-headed households. Terracing is labour intensive and if female-headed households face labour constraints then this is straightforward explanation. Hence, they are likely to adopt alternative SWC measures that are less labour intensive.

The effect of education on the decision to adopt is controversial. In their review, Knowler and Bradshaw (2007) show incidences of insignificance and even negative correlation between formal education and adoption. A review of 21 analyses of the adoption of conservation agriculture, insignificant correlation between formal education and adoption was reported for 11 analyses. One reason for this could be that the relationship is site specific. Welch (1978) discovered a positive relationship between formal schooling and agricultural practices in regions that are in the midst of modernization, but not in traditional ones found in many developing countries. In small-scale farming systems similar to Rwanda, farmers' efficiency in resource allocation is determined largely by sharing experiences with neighbours, access to extension services, field visits, and less so by formal schooling. Informal education (such as trained in agricultural techniques, participation in formal or informal field visits and in extension meetings) is expected to explain decisions about adoption of bench terraces in the study area better than formal education. Table 2.1 suggests a positive and significant impact (at the 5% level) of the head's informal education on the adoption of bench terraces while the head's formal education is negative/positive and statistically insignificant.

Table 2.1
Probit ML, bivariate probit ML, and 2SLS values of current adoption of bench terraces

Estimation option	Probit ML	Bivariate probit ML[1]		Classic 2SLS
Variables/Equation	Eq. (1)	Eq.(1)	Eq. (3)	Eq.(1)
(i) Endogenous variables				
Adoption (dummy)			1.861**	
Family income (agriculture)			0.170	
(ii) Socio-economic characteristics				
Female head	-0.274**	-0.247*		-0.116***
Age of head	-0.007	0.010		-0.0004
Age of the head (squared)	3.85E-06	-0.00004		0.00003
Family size	0.051	-0.088		0.009
Farm size	-0.067	-0.088		-0.016
Head's informal education	0.356**	0.41***		0.094***
Head's formal education (years)	-0.002	0.009		0.003
Total livestock units (TLU)	0.035	0.041		0.002
(iii) Geophysical characteristics				
Gentle slope	0.339***	0.366***		0.091***
Steep slope	0.482***	0.512***	0.024	0.145***
Very steep slope			0.821	
High erosion potential	-0.674***	-0.681***	0.378	-0.188***
Moderate erosion potential	-0.230**	-0.250**	0.116	-0.085**
Altitude (m absl)	0.001***	0.001***	-0.0009	0.005***
Distance (walking minutes)	-0.017***	-0.016***	0.02***	-0.004***
Ln Plot size	0.132**	0.137**	-0.073	0.035***
(iv) Institutional factors				
Collective action (farmers)	2.203***	2.232***	-0.135	0.618***
Land tenure security	0.120	0.150	-0.003	0.031
Association membership	-0.119	-0.149	0.058	-0.039
Program support (village level)	-0.110	-0.135	-0.367**	-0.044
(v) Perception related factors				
Perceive benefits of B. terraces			0.343*	
Constant	-3.939***	-3.728***	-0.223	-0.675***
Regression siagnostics				
Wald Chi-square	151.22		357.22	
Probability > χ^2 /Prob>F	0.000		0.000	0.000
Pseudo *R*-square / R-Square	0.21			0.242
LR	-449.97		-933.87	

/athrho		-0.404*	
Sample size (*n*)	904	895	859
Replications (Boot)	97	100	

* P $\prec$ 0.1, ** P $\prec$ 0.05, *** P $\prec$ 0.01 ; 1: Seemingly unrelated bivariate probit of Eq.(1) and Eq.(3)

Geophysical characteristics associated with erosion risks, such as slope steepness, high or moderate potential soil erosion, altitude, plot size, and distance between the plot and the homestead, are important in the design and adoption of soil conservation measures such as bench terraces. The gentle and steep slope parameters are important factors explaining in adoption – significant at the 5% and 1% levels, respectively. Soil erosion might occur on plots within one slope category or another; however, the presence of different erosion rates needs serious consideration of protecting the land through bench terraces and other less erosive forms of land use (Clay *et al.,* 1998). Plots with gentle slopes are generally not appropriate for bench terraces. However, due to food-for-work or cash-for-work incentives used by some of SWC interventions in the study area in the past, some plots with gentle slopes were bench terraced while they were meant for alternative and less costly SWC techniques such as progressive terraces. This recalls the need for sufficient consideration of technical aspects during SWC interventions. The negative sign of high and moderate erosion potentials is probably due to the fact that these erosion levels are associated to unterraced plots (i.e. endogenous variable) and that they are more associated with the decision about future adoption (Eq.(3)) rather than current adoption. This is verified in the subsequent estimation of future adoption.

Altitude (m absl) is an important factor in the adoption of bench terraces (at the 1% level) – that is, households from villages/sub-cathments located in mountainous areas tend to suffer more from the threat of erosion than those in lowlands due to higher rainfall. Thus, there is a higher chance that they adopt bench terraces to counter potential soil erosion. It is also evident from the analysis that most of terraced plots are near the homestead. The estimated coefficient of the distance parameter is negative and significant, even at the 1% critical level. This can be supported by the fact that farmers prefer to cultivate plots that are close to their homes for easy transportation of fertilizers such as manure and household residues. Therefore, if a new technology is introduced, the plots close to the homestead are the most targeted by farmers, all else being equal. It is also clear from the analysis that the larger the plot, the more likely farmers are to integrate bench terraces in their farming (significant at the 5% level). In other words, farmers who adopted bench terraces have relatively large plots. Fixed infrastructures such as bench terraces are associated with different investment risks, which make smaller farmers reluctant to adopt, especially when profit levels are unclear in the first phase of technology adoption (Clay *et al.,* 1998).

Some of the institutional and social capital characteristics hypothesized to explain the adoption of bench terraces include collective action, land tenure security, association membership, and programme support. Only collective action affects significantly the current adoption of bench terraces at the 1% level. Different types of labour were used to construct bench terraces in Rwanda. These comprise labour paid by SWC programmes through food or cash for work, own labour, hired labour, prisoner's labour within the current TIG programme, and collective labour mobilized by farmers themselves through various social arrangement (e.g. mutual assistance) or via small associations. In many cases of soil conservation with intensive labour inputs, farmers use the potential of their social capital to address many of the economic constraints, including labour. As also observed in the Machakos district in Kenya (Nyangena, 2008), farmers in the study area take turns developing bench terraces on their own plots. While controlling for other factors, the availability of such social arrangements represents alternative assets that can have positive effects on farmers' decisions to adopt terraces on their private lands.

Unexpectedly, programme support is negative and not significant, making it not an easy parameter to explain. It is possible that the majority of terraced plots (about 65%) are from sectors that did not receive support from World Vision International, which might explain the negative association between adoption of bench terraces and programme support.

6.5.2 Farmer's capacity to invest in bench terraces

Previous studies on adoption, as prominently reviewed by Feder *et al.* (1985) and Knowler and Bradshaw (2007), sustain that household characteristics (e.g. age, family size, farm size, education) do not explain regularly farmers' adoption decisions. While keeping constant the context and the approach used to introduce a new conservation technology, these factors show more an indirect link with adoption than a direct one. Typically, these characteristics affect other people's economic outcomes such as income, which, in turn, can affect directly the decision to adopt. Consistent with the analysis (Table 2.1), most of these characteristics do not explain significantly the decision to adopt bench terraces. In this analysis, socioeconomic household characteristics are hypothesized to affect future adoption via farmers' income (proxy for farmers' capacity to invest), among others. The assumption of the indirect links with future adoption was the reason why they were not included initially in equations (3) and (5). Here, the interest is to obtain estimates of socioeconomic factors that explain the capacity to invest in terraces (Eq.(2)). In turn, the effect of farmers' capacity to invest on future adoption is assessed (Eq.(3)).

Factors expected to influence the capacity to invest include cash flow, experience, family size, available labour, farm size, essential skills measured by formal and informal education, livestock, off-farm income, and other family resources (Gebremedhin and Swinton, 2003; Shiferaw *et al.*, 2009). Per capita family income (from agriculture) is used as a proxy for farmers' capacity to invest. Across the OLS and the 2SLS estimations, female head, total livestock units (TLU), and off-farm income explain consistently and significantly farmers' capacity to invest in terraces (at the 1%, 5%, and 10% levels). On the other hand, family size, farm size, head's formal and informal education, and available labour seem to be important only when the 2SLS technique is applied to assess the whole system of equations together under option (3).

Female head and family size have negative and significant influences on farmers' capacity to invest when measured by per capita family income. The negative effect of female head suggests that households headed by a female are likely to have lower income compared to those with male heads. This is consistent with the literature that in most developing countries like Rwanda, men have more off-farm opportunities than women, thus increasing the household income compared to female-headed households. In addition, family size is regarded in adoption researches as a measure for labour availability or the need to feed more people (Gebremedhin and Swinton, 2003; Bizoza *et al.*, 2007). In this study's context, it is viewed as the need to feed more people. Rwanda has a large family size of about six children (2007 baseline). Also, a high family dependency rate of 37% (SD=0.24) can be observed within the study population. Looking at the results, this would imply, *ceteris paribus*, that the more children a family has to feed, the more the capacity to invest is negatively affected.

Table 2.2.
Coefficient values of farmers' capacity to invest in and future adoption of bench terraces

Estimation option	OLS (1.2)	2SProbit ML (a)	2SProbit (b)	2SProbit (c)	Classical 2SLS	
Variables/ Equation (number)	Eq.(2)	Equ. (3)	Eq.(3)	Equ.(5)	Equ. (2)	Eq. (3)
(i) Endogenous variables						
Adoption (dummy)	0.169*	1.803**	0.438***	2.22***	0.002	0.42*
Farmer's capacity to invest		0.207	0.251*	-0.008		0.085***
(ii) Socioeconomic characteristics						
Female head	-0.277*				-0.297***	
Age of head	-0.022				-0.022	
Age of the head (squared)	0.0002				0.0002	
Family size	-0.066				-0.061**	
Available labour	0.1264				0.1268***	
Farm size	0.0005				0.0005***	
Head's informal education	0.194				0.207**	
Head's formal education (years)	0.018				0.018	
Total livestock units (TLU)	0.401***				0.403***	
Off-farm income	6.90E-07***				6.70E-07***	
(iii) Geophysical characteristics						
Steep slope		0.027	0.123	0.046		0.041
Very steep slope		0.903**	0.732**	1.168***		0.2167**
High erosion potential		0.354*	-0.126	0.392*		0.128*
Moderate erosion potential		0.121	0.037	0.128		0.045
Altitude (m absl)		-0.0009	0.0001	-0.001*		-0.001
Distance (walking minutes)		0.021***	0.015**	0.022***		0.005****
Ln Plot size		-0.079	-0.075	-0.084		-0.031*
(iv) Institutional factors						
Collective action (farmers)		-0.146	0.723**	-0.403		-0.062
Land tenure security		-0.005	-0.041	0.012		0.034
Association membership		0.0513	-0.055	0.104		-0.004
Program support		-0.360**	-0.416	-0.405**		-0.112***
(v) Perception factors						
Benefits of terraces		0.362**	0.355**	0.373**		0.094***
Constant	10.912***	-0.668	-2.372	-2.00	10.941***	0.144
Regression diagnostics						
Wald Chi-square		58.70	64.28	64.28		
Probability > χ^2 /Prob>F		0.000	0.000	0.000	0.000	0.000
Pseudo R-square / R-Square	0.264	0.115	0.1203	0.1203	0.2608	-0.0106
LR		-495.17	-4792.96	-4792.96		
Sample size (*n*)	860	895	896	896	859	859
Replications (Boot)	100	94	90	84	100	100

Notes: * P $\prec$ 0.1, ** P $\prec$ 0.05, *** P $\prec$ 0.01
(a) Two-stage probit ML of future adoption (Eq.(3)) with first-stage estimates of Eq. (1) and (2) under option (1)
(b) Two-stage probit ML of future adoption (Eq.(3)) with first-stage OLS estimates of Eq.(2) under option (1)
(c) Two-Stage probit ML of future adoption (Equ.(5)) with first-stage probit ML of Eq. (1) under option (2).

The positive and significant coefficient of the endogenous dummy adoption variable in equation (2) suggests that current per capita household income is to some extent affected by prior adoption of bench terraces. However, no robust evidence exists that early adoption affects farmers' capacity to invest. Relying on the estimate of dummy adoption, it can be concluded that the farmers who adopted terraces in the past have higher and significant differential incomes than non-adopters (at the 10% level). The extent to which bench terraces contribute to household income needs further investigation; this lies beyond the scope of this article.

6.5.3 Future adoption of bench terraces

At this stage, the assumption is tested that current adoption and farmers' capacity to invest in inputs affect future adoption of bench terraces. Also, factors related to geophysical, institutional, and perceived benefits of bench terraces are identified to explain future adoption. Some of the geophysical and institutional factors specified for future adoption (Eq.(3)) are the same as for current adoption (Eq.(1)). However, the scale and the direction of their impacts can be different from the other two equations.

It is interesting to note (see Table 2.2) that farmers with very steep plots are willing to adopt bench terraces in the future (significant even at the 1% level). Land scarcity is evident in Rwanda. As a result, marginal and very steep lands are now being cultivated by farmers. This is likely to accelerate agricultural erosion due to soil run-off (Lewis and Clay, 1990). For these very steep lands to be cultivated, they need to be terraced for two reasons: to increase agricultural production and to counter soil erosion. Likewise, plots located in areas with high erosion potential have a positive and significant association (at the 10% level) with future adoption of bench terraces. This is consistent with the theory that farmers who live on steep lands, like in Rwanda and elsewhere in the tropics, are likely to face more soil erosion effects and hence will adopt SWC measures such as bench or stone terraces. Farmers in lowlands face relatively less erosion and can use alternative techniques such as slow-forming terraces and other endogenous soil erosion control measures.

Distance from plot to home appears to have a positive and significant impact on future adoption (at the 1% level), unlike in the adoption equation (Eq.(1)). It implies that even plots in areas remote from the homestead will be terraced in the future. Among other things, this is due to increased concern for soil erosion problems, land scarcity forcing the cultivation of plots isolated from home, and famers' perception of the benefits of bench terraces. Descriptive statistics support the thesis that farmers are well aware of the benefits of bench terraces, in the sense that they increase production or have positive effects on production (85.3%), that they are effective for soil erosion control (90.6%), and that they increase soil fertility (56.2%). This awareness has been documented in the literature as conditional adoption (Saha *et al.*, 1994; Dimara and Skuras, 2003). Results from regression analysis echo the descriptives that perceived benefits justify farmers' willingness to develop new bench terraces in the future (significant at the 5% and 1% levels).

The unexpected negative impact of programme support on future adoption is difficult to explain (significant even at the 1% level). It was expected that sectors receiving SWC support would be willing to choose more terracing than not supported ones, all else being equal. The analysis reveals that the more farmers receive support from SWC programmes, the less they are willing to construct new terraces without SWC support. This is perhaps due to the dependency mentality as a result from past SWC interventions, which used incentives for terrace construction in individual or public plots throughout Rwanda. Consequently, some farmers tend to believe that terracing is a social good to justify public intervention rather than individual investment. Second, farmers in sectors that received support previously are less likely to receive more support for terrace construction in the future. Furthermore, the negative impact of support programmes on the future adoption of bench terraces may have been caused by the fact most suitable plots in supported sectors have been terraced already. Earlier studies also maintain that a combination of material incentives and direct public involvement in constructing SWC structures on private land undermines the individual motivation for private investment in soil conservation and may result to abandonment once the incentives are withdrawn (Bunch, 1999; Winters *et al.*, 2004; Gebremedhin and Swinton, 2003). However, further research is needed on how public and private investments in SWC work out in Rwanda.

Predicted farmers' capacity to invest (from OLS estimates of Eq.(2)) and the prior adoption dummy were calculated by altering the specification of Eq.(3). Out of four alterations, two-step probit ML and classic 2SLS estimates show that predicted farmers' capacity to invest has a positive and significant impact on future adoption (at the 10% and 1% levels, respectively). This applies when Eq.(2) and Eq.(3) are estimated together using two-step probit ML and when the whole system (Eq.(1) to Eq.(3)) is estimated by the 2SLS method. Prior adoption measured by a dummy (option b) and as a predicted variable (options (a) and (c)) is statistically significant (at the 5% and 1% levels) in the four alterations (see Table 2.2). In addition, these results support the thesis that explanatory variables specified for farmers' capacity to invest have an indirect and significant effect on the future adoption of bench terraces (at the 10% and 1% levels). Again, these findings verify the assumption made in this paper that farmers' capacity to invest and early adoption are important factors explaining future adoption, all else being equal. Their marginal effects (sample mean=0.7099) are found to be statistically significant at the 10% and 1% levels , respectively. They help to put into perspective the marginal effects of farmers' capacity to invest ($dy/dx = 0.0859$) and early adoption ($dy/dx = 0.1415$) on the future adoption of conservation agriculture in the highlands in Rwanda.

The results presented in this paper shed light on the question whether farmers are willing to construct more or adopt new terraces beyond current adoption and after extensive SWC programme interventions. The response lies, *among others*, in the farmers' capacity to invest not only in the development of new terraces but also to supply other necessary inputs required to use on existing and new terraces. Also, the results show that farmers are willing to construct more terraces but that this is restrained probably by their inability to invest in complementary inputs as well as in terraces. Survey results confirm that farmers are aware of soil erosion as a problem and of the potential benefits of bench terraces. However, the challenge remains the capacity to invest in order to optimize this knowledge. From these findings, one can conclude that farmers' perceptions of soil erosion as a problem and of the benefits of bench terraces are necessary but not sufficient conditions for future adoption of the same technique. Farmer's capacity to invest in existing or new terraces fulfils both the necessary and sufficient conditions for future adoption. Improving farmers' incomes and hence their capacity to invest should receive particular interest for further interventions in conservation agriculture and for the overall development of farming systems in Rwanda.

6.6 Conclusions

Recent studies show the need for a dynamic analysis of technology adoption rather than the usual static procedure. This paper went beyond the adoption decision model and investigate whether farmers are willing to adopt new bench terraces in Northern and Southern Rwanda. A three-stage analysis was used to estimate the current and future adoption decisions of bench terraces and farmers' capacity to invest in bench terraces. Unlike previous studies that modelled farmers' decisions to adopt bench terraces on those who had already adopted, here continued adoption of bench terraces was 'unpacked' to consider both adopters willing to increase the use of already constructed terraces and non-adopters willing to develop new terraces. The analysis focused on whether farmers would adopt bench terraces conditional upon their capacity to invest in complementary inputs and upon early adoption of bench terraces elsewhere in their respective villages.

Major findings of the analysis sustained the thesis that future adoption of bench terraces in the highlands of Rwanda depends on farmers' capacity to invest in, early adoption of, and perceived benefits of bench terraces. Consistent with many other studies in the literature, the analysis supported the theory that farmers' capacity to invest represents a long-term perspective on soil conservation and should receive attention when technologies are being introduced for conservation agriculture. Both early adopters and non-adopters of bench terraces are willing to adopt more or new bench terraces. A possible explanation for this lies in the perceived benefits of bench terraces as they have a positive and important impact on future adoption. In other words, these perceived benefits justify why farmers are willing to take up more or new bench terraces in the research area, all else being equal.

In accordance with previous studies, a second empirical result was that some socioeconomic, geophysical, and institutional factors determine current and future adoption. Female head of household and head's informal education are important socioeconomic factors to explain observed adoption of bench terraces (Eq.(1)). Important geophysical factors estimated include gradient/slope, potential erosion levels, altitude, distance, and plot size. These factors had significant effects on both current and future adoption decisions but with different magnitudes and directions of their respective effects, depending on altered specifications of future adoption (Eq.(3)). Again, among institutional factors specified, collective action seemed to have an important effect on the adoption of bench terraces. This implies that some farmers adopted bench terraces because they were able to mobilize labour due to involvement in labour pooling within different social arrangements. In combination with perceived benefits of bench terraces, it can facilitate farmers to address labour needs in the construction of future terraces.

Finally, the analysis showed that farmers are willing to take up new terraces (19% of late adopters). However, their capacity to invest in inputs required to use and construct new terraces is a key constraint on the materialization of said willingness. In view of the above, this paper recommends that particular attention should be focused on how to improve farmers' capacity to invest in inputs for sustained interventions in soil and water conservation. If this is ensured, farmers will achieve both goals of soil erosion control and increased agricultural production as well as improve current farming systems in Rwanda.

CHAPTER 7

RESULTS AND CONCLUSIONS

7.1 Introduction

This thesis has dealt with questions related to soil and water conservation issues in Rwanda. The main objective was to increase the understanding of the complexity of soil erosion problems with a specific focus on how farmers and a variety of institutions affect the adoption and effectiveness of soil and water conservation measures in Rwanda.

This final chapter aims to bring the conclusions of the various chapters together in an attempt to draw some main conclusions with which to seek active engagement with policy-makers.

7.2 Discussion of key results and conclusions

Major results are summarized and discussed with reference to each of the four specific question(s) raised in the introductory Chapter 1.

SWC measures that have been used and the processes of their implementation in Rwanda

The first specific question was addressed in Chapter 2 of this thesis and states: what soil erosion control measures have been used from the pre-colonial era to the independent state in Rwanda? There is evidence that soil erosion had been recognized as a problem among both political authorities and farmers during the pre-colonial period and during the early colonial period. Since then, soil conservation measures have been applied over time and under different government regimes. In pre-colonial times, SWC measures consisted primarily of *inyanamo* (strip-cropping), meant to create some space between cultivated areas as fallow, and *rudumburi* (stone rows), used to protect the land from 'run-off' (fluvial erosion). However, implementation of these techniques was rather small in scale. Later on, during the colonial era, the German and Belgian administrations introduced and enforced a number of SWC techniques and regulations. These included construction of hedgerows, keeping spaces between farms for movement of livestock, digging of trenches in combination with hedgerows, and planting exogenous tree species such as eucalyptus. Farmers and technicians contested, destroyed, and abandoned some of these techniques as they were imposed alongside fines and imprisonment for non-adopters. The abandonment of these techniques by farmers was interpreted as an expression of regained freedom lost earlier at the hands of the colonial powers. Clearly, these top-down and coerced measures forced farmers to participate and did not give them space to appreciate potential and respective benefits (and costs) of each technique in order to decide whether or not they would want to adopt them. Later on again, in the era of independent government, the only new SWC measures were new hedge varieties (both for mulching and as fodder for livestock), agroforestry species, and bench terraces. After the 1994 war and genocide, the government enforced the construction of more terraces through various political and development policies such as the performance contract (*Imihigo*) and the 'model hill' (*Agasozi Ndatwa*), detailed in Chapter (3).

The colonial and post-colonial states implemented large-scale investments through mostly imported measures such as bench terraces for soil erosion control. Despite past and ongoing efforts of the state to promote imported and modern SWC techniques, farmers may still use indigenous SWC techniques. These indigenous measures were tried either inadequately or not at all before introducing the above-mentioned structural measures (Hurn *et al*., 2008). However, these have been documented hardly at all in the literature; this constitutes a potential area for further research.

In the history of soil erosion control, population pressure and land tenure have been regarded to be important development challenges to have shaped SWC interventions in Rwanda. Nevertheless, concern was more about soil erosion control than about finding connections with population control and security of land tenure. It is concluded that a 'big family' on a 'fixed' piece of land are two conflicting believes that restrain land conservation and management in Rwanda. In order to escape this doom scenario, it is suggested that more efforts are put into diversifying the rural economy towards social and economic development in Rwanda.

Farmer participation, role of farmer organizations, and effectiveness of SWC measures

The objective in Chapter 3 was to respond to the second specific question: how do farmers participate in soil conservation and how do state–farmer relationships affect soil conservation strategies in Northern and Southern Rwanda?

In soil conservation, farmer participation is usually measured by participation in the SWC programme in terms of whether or not incentives and services have been received, and also in the sense of supplying labour and land to easy SWC interventions. In this study, farmer participation was examined via their 'decision-share' during the design and implementation of SWC measures in Rwanda. Specifically, it was assessed whether farmers were involved in the decision-making process with respect to soil and water conservation measures. Bench terrace construction served as reference to inform who decides 'when and where' to construct terraces in the study area. Various actors involved in soil erosion control were pre-listed and pre-coded during the focus-group discussion and subsequently in the large farm survey: farmers themselves, their organizations, local leaders, and extension officials.

Results showed that farmers play a marginal role in the decision 'when' and 'where' to establish terraces within their respective communities. Their participation involved mainly consultation about and self-mobilization in SWC measures. Development officials, including local leaders, still played a major role in the planning and implementation of SWC measures in the study area. Lower levels of decision-share of farmers has implications for ownership and sustainability of SWC measures in Rwanda. The more the government and NGOs are involved in terrace construction, the more farmers' roles are evicted and hence the less responsible they will feel for terrace maintenance. Some experiences from Jamaica, Ethiopia, and Kenya show that farmers justified their resistance to maintain built terraces by arguing that it was government money that had built them, so it should be the same government money that should maintain them (Blustain, 1985: 128). It remains a challenge to come up with a development approach(es) that can sufficiently involve farmers (users) from the early stages of implementation of SWC measures. This could allow them to view established SWC structures not as societal goods but as their own structures, which they need to maintain and to effectively use for more years. This could also eventually reduce the direct role of local leaders, extension officials and, hence, of the state in soil conservation on private lands.

In the last 30 years, small-scale farmer organizations have been regarded as major local institutions through which farmers deal with their day-to-day needs. Farmers join their associations in order to access some of the resources needed and to share agricultural implements (Nyangena, 2008). Diverse social capital constituents such as 'mutual assistance' (known as *gufashanya* in Kinyarwanda) and 'group or collective action' emerge from these farmer organizations to serve the commons. For instance, during the building of terraces, the farmer associations facilitate collective pooling and sharing of labour with individual farmers to construct and to ensure (to some extent) management of common or public terraced plots. These collective actions backed by the 'mutual support spirit' allowed some households to construct and maintain terraces on their individual plots in the study area. These results support the thesis that farmers may deploy alternatives to address labour constraints in terrace construction. However, lack of liquidity to supply complementary material inputs to maintain and to continue to use terraced plots is reported and remains one of the main challenges to confront in their farming strategies.

Farmer organizations and their institutions co-operate with other government-led institutions and policies. Results of this thesis (see Chapter 3) revealed great political skills to crafting institutions from the traditional Rwandan forms of organization in order to facilitate state–farmer relationships in achieving different development goals. Policies such as *Umuganda*, *Imihigo*, *Ubudehe*, and *Agasozi Ndatwa* are drawn from traditional Rwandan society and are adapted to address contemporary soil erosion issues, among other development challenges. The core part of such an institutionalization process is to encourage the ideas of collective action, mutual assistance, and a mentality of self-reliance in tune with the spirit of competition and competitiveness. Earlier SWC interventions, especially those that used food for work under USAID support, misguided farmers in the sense that they created the dependency mentality through the use of material incentives and other short-term support. The 'self-reliance mentality' is, therefore, being re-engineered by the government through such institutions to address various development challenges and to guarantee long-term and self-sustained agriculture development in Rwanda.

Farmers' perceptions about the technical effectiveness of terraces made before and after 2006 have been investigated too. Results substantiated that terraces made before 2006 suffered technical shortfalls. Most of these terraces were constructed collectively using food-for-work and cash-for-work incentives. Farmers involved in terracing public and private lands were primarily concerned with accomplishing the task and getting paid the food ratio or the amount of cash due. Less attention was paid to the technical standards required to constructing a terrace in some areas. As a result, soil nutrients of terraced plots were disturbed, explaining increased use of fertilizers to regain soil fertility and some plots being abandoned or not used fully by farmers. In a situation of extensive use of subsidies and other material incentives to conserve soils, Blustain (1985) points out that farmers view their participation primarily in terms of immediate cash rewards rather than long-term resource conservation benefits.

In contrast, bench terraces constructed after 2006 were perceived to be technically well made. The reason being that these were developed after cognizance of some technical principles that were not much considered by farmers in the past: saving nutrient soils and spreading them following the terrace lay-out, better construction and grassing of terrace risers, and the details of spacing a terrace – all of which depended on the steepness of the plot (see also Chapter 4 for soil suitability). These findings highlighted the need of farmer training before and during collective soil conservation so that future maintenance and user costs can be avoided or reduced (Anderson and Thampapillai, 1990).

Findings in this thesis also supported the customary knowledge that programme support is not evenly distributed within the study area (Bingen and Munyankusi, 2002). Farmers in remote areas received less support compared to those bordering the town or district administrations. It reflects some geographical biases of programme intervention in soil conservation. In addition, this support 'basket' contained more about payment of labour for terrace construction. The supply of credits to acquire agricultural inputs and to market crops received fewer attention, while farmers claimed this to be the main restraining factor to terrace adoption and to their faming activities.

Financial returns of bench terraces

Do farmers with bench terraces receive higher investment returns from cultivating plots compared to those with slowly forming terraces or plots with no terraces at all? This question was addressed in Chapter 4. Terraces may reduce soil erosion and increase production but they should also provide sufficient financial gains at the farm level. Little is known about the attention paid to the suitability of the soils and to the eventual financial profitability of bench terraces for farmers in Rwanda. Descriptive analysis in this study showed that farmers were aware that the benefits of bench terraces were increased productivity (85.3 per cent), increased soil fertility (56.2 per cent), and effective for soil erosion (90.6 per cent). However, this was not sufficient to explain effectiveness of bench terraces from the farmers' perspective. Financial returns of bench terraces were hypothesized to impact the adoption and the maintenance of terraces by farmers.

Plot-level financial cost–benefit analysis (CBA) was used to examine under which social and economic conditions bench terraces are financially viable in Northern and Southern Rwanda. The analysis focused on the most common cultivation: potatoes as the dominant cash and subsistence food crop in the research area. A plot-level CBA compared two cases: subsidized bench terraces (SBT) and non-subsidized bench terraces (NSBT) as the 'with' case and non-terraced plots as the 'without' case. Results showed that SBT are not profitable when market prices are applied. The NPV was negative (–47384 Frw)[8] and the IRR (11 per cent) was lower than the discount rate of 13 per cent. A possible explanation is that subsidized households have a (too) large plot size but do not use it fully due to a lack of liquidity, among others. In contrast, the NSBT seemed to be just about profitable when considering both the positive NPV (27959 Frw) and the IRR (14 per cent) criteria.

Labour and manure form major parts of the operating costs and their markets are also imperfect. The formal price of labour and the market price of manure are relatively high. Given that the labour and manure used are from the family and their farms, an opportunity cost of 50 per cent of the market value was alternatively applied. When this option was considered, SBT were financially viable, with an IRR of 25 percent. Positive NPVs and IRRs higher than the discount rate (13 per cent) were observed for NSBT, even with no opportunity cost for labour and manure. It is, therefore, concluded that bench terracing can be a financially viable option for soil and water conservation, when either costs of labour and manure can be reduced or more intensive use can be made of the terraces. Profitability explains, in turn, the likelihood of continued use of bench terraces beyond SWC interventions in Rwanda. Furthermore, it is concluded that adoption of terraces is necessarily but not sufficiently explained by its profitability in the study area (Lutz *et al.*, 1994). Anderson and Thampapillai (1990) arrived at a similar conclusion that projects and other interventions in soil conservation should be justified by being both ecologically sound and economically viable. The challenge for policy

[8] 1 US$ equals an average 550 Rwandan Francs

intervention is to pay attention not only to soil erosion control but also to the eventual financial profitability of established terraces. However, financial profitability does not provide the entire explanation of adoption and maintenance of bench terraces. Other factors may also contribute to this explanation (see Chapters 5 and 6).

The successful construction of terraces requires a good analysis of soil suitability. An attempt was made in this study to investigate on which soil types terraces were built, using farmers' classifications of soil types (see details in section 4, Chapter 4). Results indicated that both bench terraces (33 per cent) and progressive terraces (35 per cent) were established mostly on *Urunombe* soils (Nitosols high in loam and clay) and found proportionally less on *Mugugu* soils (Ferralsols), with 19 per cent and 11 per cent of bench and progressive terraces, respectively. The effectiveness of terraces established on *Urunombe* soils depends mainly on the depth of the soils and whether the soils are (not too) compacted. In some situations, low permeability of these *soils* are vulnerable to a type of soil erosion known as *isuri ya nyamurigita*, which is observed by farmers and which has destroyed their terraced land. It brings about the need for sufficient technical guidance during terrace construction to lower maintenance costs. Unlike on *Urunombe* soils, the effectiveness of bench terraces established on plots with *Mugugu* soils (Ferralsols) will depend more on soil fertility and less on soil permeability. Considering relatively good drainage on *Mugugu* soils, crop performance on terraces can be explained by other factors, including subsequent use of fertilizers, farm management and, in particular, the inherent variation of physical and chemical soil properties (Kannan *et al.*, 2010; Siriri *et al.*, 2005).

Local institutions and adoption of bench terraces

In Chapter 5, responded to question 4: Which factors explain current and future adoption of terraces in Northern and Southern Rwanda? The main point was to find out which institutional and geographical factors were relevant for explaining adoption of terraces in the research area. Two equations were constructed. The institutional variables identified for model estimation included tenure security and social capital measured in terms of trust, co-operation in collective action and membership of farmers' associations/organizations. Echoing earlier work on adoption of agricultural technology, some geographical, farm and household, and plot-level variables explained adoption of bench terraces. The findings showed that farmers seemed to focus their terracing efforts on plots that were relatively large, steep and close to their homestead. Family size and informal education in terms of training and field visits did have significant impacts on the decision to invest in bench terraces.

Furthermore, the impacts of different dimensions of social capital on the adoption of bench terraces was explored. It was found that trust and collective action had a positive and significant effect (at the 1 per cent level) on the adoption of bench terraces. Contrary to previous studies (e.g. Nyangena, 2008; Rezvanfar *et al.*, 2009), membership of farmers' associations/organizations had a negative and not significant association with bench terrace adoption. With these results, it was concluded that some dimensions of social capital (trust and collective action) were conducive to the adoption of bench terraces. None of the institutional variables explained adoption of progressive terraces.

Empirical findings in Chapter 5 reflected that social and institutional arrangements were required more for establishing bench terraces than for progressive terraces. This suggests that the more a given technology is demanding in terms of labour inputs, the more farmers are likely to rely on reciprocal forms, such as sharing of labour and agricultural implements (Nyangena, 2008). In other parts of this thesis, it has been indicated that many interventions in soil erosion control in Rwanda focused more on establishing soil and water conservation structures than on their subsequent use by farmers. Results from Chapter 5 echoed the qualitative insights obtained in Chapter 3 that farmers can still support the establishment costs of bench terraces through social arrangements. Hence, further efforts from government organizations and NGOs should focus on the supply of material inputs such as fertilizers and improved seeds needed for the subsequent use of established SWC structures.

Tenure security did not explain adoption of either bench or progressive terraces. There is a general understanding in the literature that tenure security is necessary for investments in land conservation. However, results in this thesis showed that tenure security may not be a necessarily condition to soil conservation adoption because customary land rights are functioning well. About 80 per cent of survey respondents confirmed that they felt land secured. Therefore, land tenure security may depend on other factors, which, in turn, may impact on adoption of bench terraces. Therefore, it was suggested that better analysis of the impact of tenure security on investments in soil conservation in Rwanda is needed beyond the microanalysis that has guided past research on agriculture adoption.

Typically, findings in this thesis support the growing scientific debate that local institutions matter in investments in soil and water conservation. However, not all forms of institutions are found relevant in the present case. Therefore, whether formal or traditional land rights are conducive to the adoption of soil conservation measures should be considered context specific and remains open to empirical debate in Rwanda.

Adoption and farmers' ability to invest in bench terraces

Chapter 6 deals also with question 4: which factors affect farmers' current and future decisions about adoption of bench terraces, focusing on their capacity to invest in inputs in Northern and Southern Rwanda? Farmers' capacity to invest has been overlooked by some SWC interventions; however, it is an important long-term investment perspective (Gebremedhin and Swinton, 2003). It was argued that terracing that does not fit farmers' capacity to invest in additional inputs may explain why some of the established terraces in the study area are not maintained and used effectively by farmers. The literature on adoption and continued use of conservation agriculture was expanded by 'unpacking' the adoption process of bench terraces in Rwanda. Different econometric models were applied to analyse the adoption of bench terraces in a three-stage procedure. Both data from household and plot levels were used to estimate a system of three equations (see Chapter 6).

The empirical results supported that some geophysical, socioeconomic, and institutional factors determine current and future adoption of bench terraces. Farmers' capacity to invest was determined by socioeconomic factors, which in turn had an indirect effect on future adoption. The size and the direction of specified vector variables in all equations differed from one specification to another. Female head and head's informal education were important socioeconomic factors explaining the current adoption of bench terraces in the study area. Head's informal education was a more important estimated factor to adoption (significant at the 5 per cent level) than head's formal education in the study area. If new soil conservation technologies are to be introduced and to call for farmers' decisions to adopt, then informal education should receive extra attention before and during technology performance. This can be translated into field experiments/visits and other training approaches as is well documented in the existing literature on technology adoption and diffusion.

Another keyed result was the relative significant impact of social capital in terms of trust and collective action in the construction of bench terraces (significant at the 1 per cent level). The analysis showed that some farmers adopted bench terraces because of labour pooling through social arrangements made it easier to construct terraces on their private plots. This validated empirically the qualitative effect of 'mutual assistance' on terrace adoption maintained in Chapters 3 and 5: collective action constitutes an important feature of social capital, which substitutes the sometimes unaffordable costs of labour and the absence of credits for soil erosion control using terraces. Future interventions in soil conservation by government organizations and NGOs based on these farmer-led collective actions can decrease soil erosion. However, the challenge ahead that needs further investigation is how this 'collectiveness' can be maintained in a society where labour is being commoditized or monetized. In other words, these collective actions will persist only in certain conducive contexts such as the ongoing institutionalization process (detailed in Chapter 3) or in a situation of imperfect and/or less-developed labour markets.

Positive and significant effects of distance to and very steep slopes of the plot are two geophysical factors that need closer attention in future land conservation. What these findings imply is that, due in part to scarce land resources, farmers will possibly construct terraces even on remote and very steep plots, which were deemed not suitable for bench terrace construction previously (Siriri *et al.,* 2005). Hence, increased soil erosion effects are to be felt more than before if no extra measures become available. These results point to the need for strategies to increase crop production on available land and to terrace lands that are appropriate. Marginal and steeper lands can serve other purposes, such as tree plantation.

Finally, farmers in the study area have the intention to use existing and new bench terraces in the future. However, their inability to secure complementary inputs for existing and new terraces may explain a disinclination for future adoption of soil conservation in Rwanda. The same inability explains possibly why some of the terraced plots are not used in full by farmers, which has negative effects for both soils and crop yields. Due to the perceived benefits of bench terraces observed among farmers (significant at the 5 per cent level) and their experiences in soil erosion control using terraces, farmers require sufficient resources to optimize such knowledge to continue use and future adoption of SWC measures in Rwanda. Future interventions in soil conservation should, therefore, pay closer attention to how to improve farmers' capacity to invest in terraces as well as to their farming activities.

General conclusions

Overall, this thesis has increased the understanding of the complexity of soil erosion problems and how farmers and a variety of institutions affect the adoption and effectiveness of soil and water conservation measures in Rwanda. The vast majority of past and current studies hypothesized that socioeconomic, geophysical, and institutional factors affect adoption of soil and water conservation practices. However, this thesis concludes that in most developing countries, including Rwanda, the decision to adopt soil and water conservation measures is mostly an outcome of the state–farmer relationships. Similar to earlier studies, it is concluded that local institutions such as social capital affect the decision to adopt SWC measures. However, these local institutions are not empowered enough to ensure long-term sustainability of established SWC measures.

Bench terraces are promoted for soil erosion control through policy. However, they are expected to be more ecologically effective than economically profitable. Returns on established bench terraces are still too low to allow further investments in terraces by farmers themselves. Subsequent measures to allow farmers to use their terraced plots in full should include compulsory conditions to ensure that bench terraces are beneficial from both public and private perspectives.

Typically, perception of soil erosion as a problem, the decision to use soil erosion control practices, and soil conservation efforts are the major components of the decision-making process to adopt soil conservation measures (Ervin and Ervin, 1982). Evidence from this thesis showed that farmers can be aware of soil erosion as a problem and still not adopt soil conservation practices. Again, they can also adopt soil conservation structures but not use them effectively due mainly to their inability to supply additional material and required labour inputs. Therefore, future interventions by government organizations and NGOs should focus on how to improve farmers' capacity to invest and empower local institutions for sustainable land conservation in Rwanda.

In all the above, approaches to land conservation in Rwanda have shifted from top-down to some form of participation. The decision to adopt soil conservation measures is not solely the result of an individual decision-making process but also the result of the role played by the state and the room for maneouvre of local-level institutions. In addition, less attention is paid to the financial profitability of bench terraces when introduced by government and NGOs in Rwanda. If introduced terraces are not profitable at the farm level, this may discourage further adoption and possibly the abandonment of established terraces. Hence, more erosion is likely to occur, possibly followed by more soil erosion effects such as declining soil fertility and reduced production. Incentives such as input subsidies, if well tailored, can allow established bench terraces to reduce soil erosion effects while providing better economic returns. In addition, the decision whether or not to adopt soil and water conservation practices such as bench terraces is more than simply a one of acceptance. The capacity to invest in the subsequent use of established measures and to ensure long-term sustainability through empowering local-level institutions are part of the adoption process.

Therefore, the results of this study may contribute to the overall debate of land conservation in developing countries. In addition, the institutional and socioeconomic perspective opted in this study may increase the understanding of soil and water conservation issues in Rwanda.

7.3 Some reflections on perspectives and approaches to land conservation

The role of the state, farmer participation, incentives, and institutions are major topics drawn from the perspectives and approaches to land degradation and conservation introduced in Chapter 1. These were relevant to develop the understanding of the complexity of the soil erosion problem and of how farmers and various forms of institutions affect the adoption and effectiveness of SWC measures in Rwanda.

The role of the state was found central in the environmental discourse about soil and water conservation issues in Rwanda. Even though populist and neo-liberal approaches argue for an anti-state position in land conservation, it has been difficult to dissociate the role of the state in rural development and environmental management in most developing countries. It will always be a challenge to do so as long as development interventions bear some externalities or off-site effects, which in turn require the state and its agents to secure public goods and social benefits. This does apply not only to Southern countries but also to Northern developing countries as well as to developed ones, although with different 'clothing' or 'branding'.

The concept of farmer participation was useful in coming to grips with the perceptions of farmers about their participation, the role of their organizations and institutions, and how state–farmer relationships affect strategies for soil and water conservation in Rwanda. Farmer participation draws from the populists who argue for bottom-up development approaches in contrast to the classical or top-down development approach. One of the challenging parts of this approach is the empirical measurement of the extent to which farmers participate; it often ends up to being more subjective. The Rwandan case-study shows a 'hybrid' development approach, especially in land conservation where both government and farmer organizations and local-level institutions coexist. The emerging government policies for rural development are designed by the state from traditional repertoires aimed to foster notions of collective action, reciprocity and self-reliance. On the other hand, farmer-led institutions are found to be conducive to farmers' investments in soil conservation through the construction of bench terraces (Chapter 3 and 5). This gives an idea of how difficult it is to position the development approach opted for in Rwanda exclusively within the classical or populist development approaches. Instead, the important task is to understand how the approach functions in its historical contexts and whether expectations of the peasants from the government are met.

Incentives and institutional arrangements to induce adoption of land conservation are the two concepts that drive the thesis of the neo-institutional economics paradigm. These two concepts were helpful in exploring the adoption process of soil and water conservation measures in Rwanda. Incentives such as food-for-work used by SWC projects and consequent institutional arrangements can induce farmers to adopt soil conservation, although for the wrong reasons. Some farmers adopted not for soil erosion control reasons but for these incentives rather than for the perceived benefits (incentives) such as increased production and income due to soil conservation and improved soil fertility. In such situations, the economist's invisible hand of the market promoted by the neo-liberals does no longer play a role in allocating resources optimally (Blaikie, 2000). Also, the notion of institutional innovation remains uncertain, especially in situations where the roles of the state and of farmers in land conservation are linked.

Overall, the findings of this study have brought to the fore that one-directional thinking of development approach(es) to land degradation and conservation deserves criticism. What is needed, rather, is a multiple and interdisciplinary approach that takes into account aspects and dimensions raised by the classical, populists, and neo-liberal approaches.

7.4 Policy options

In order to understand what soil and water conservation (SWC) issues emerge during the design, implementation and continued use of established SWC structures in Rwanda, one needs to put soil and water conservation within its socioeconomic and institutional contexts. Findings in this study pointed towards policy options for the future prospects of soil and water conservation in Rwanda. However, it is difficult to suggest (an) accurate policy option(s) in a country subjected to the following threefold development challenges: small per capita land size (sample estimate of 0.7 ha), declining soil fertility, and the highest population density in Africa (376 inhabitants per km^2). In order to increase agricultural production and improve people's livelihoods under such situations, further and careful development approaches are essential to modernize current farming systems, increase soil fertility, and respond to the ever-increasing population growth.

Soil conservation has been regarded as part of the solution, shaping farmer strategies and project or policy interventions. Findings in Chapter 2 showed that more attention was given to soil erosion control per se than to the slowing population growth vis-à-vis the available land. This calls for development strategies on how to improve the land (effectively intensified land) and the overall farming system. If this is possible, then population pressure may be less problematic. Results from Chapter 2 and also from Chapter 3 underscored the marginal roles and lower farmer participation in the process of soil and water conservation in the past. The state represented by its agents (local-level leaders and extension officials) led mostly the planning and the implementation of SWC measures on both public and private lands. State–farmer relationships in soil conservation were facilitated by government policies, farmers' organizations and other institutions. These results showed how terrace construction in Rwanda encompassed not only technical dimensions but also social and institutional ones. Now Rwanda needs a development strategy that induces an indirect role of the state and that enhances farmers' capacity to innovate and adapt in response to soil erosion problems and other development challenges. The watershed development approach, as already initiated in some parts of the country, if well implemented, can promote soil conservation that is participatory and compatible to the socioeconomic conditions of farmers. This approach has been proven a better alternative in some cases such as India (Mafuka *et al.,* 2005). Under this option, government will focus more on how to support farmer initiatives through demand-driven institutions and improved infrastructure in the rural area (e.g. market institutions, road connectivity, education and health facilities). Also, large-scale implementation of SWC measures leads often to off-site effects or to public goods that still require government intervention to some extent.

The findings in Chapter 4 highlighted the need to consider both conservation benefits (reduced soil run-off and preserved water resources) and financial incentives of bench terraces. Results sustain that bench terraces can be financially profitable when either costs of labour and manure can be reduced or more intensive use is made of terraced plots. Non-use or ineffective use of terraced plots may result in negative effects. Terracing can reduce crop yields in the first years after construction if no extra fertilizers are used. Increased soil acidity is likely to occur on terraced plots when no better maintenance is ensured. For farmers to gain more benefits from bench terraces, government subsidies should be directed instead to the maintenance part of already established terraces. If well maintained, already constructed terraces can lead to the effective use of terraced plots and better financial returns will probably follow, all else being equal. This option contributes simultaneously to addressing land shortage and declining soil fertility.

The analysis in Chapter 4 showed also that some of terraces constructed earlier were destroyed due to a soil erosion type known as *isuri ya nyamurigita*. Agricultural mechanization is hardly applied in Rwanda. Terraces are hand built by farmers, difficult to replicate, and almost not renewable. Sufficient technical guidance during terrace construction and continued advice about maintenance can reduce user costs for generations to come. This advice is expected from the agronomists at sector levels whose roles are multiple rather than focusing solely on agriculture-related activities. This often justifies their excuses for insufficient extension service delivery to the farmers. If their tasks are reviewed by the government to solely focus on agriculture-related activities, this is likely to improve the quality of education and other extension services hypothesized in the literature (also supported by this thesis) to play an important role in soil conservation.

Results in Chapter 5 provided empirical evidence that local institutions such as social capital matter for the adoption of bench terraces in Rwanda. Co-operation in collective labour is an important institution resulting from social arrangements. However, such local institutions are likely to be functional when they are well recognized by policy and other interventions in rural development in Rwanda. This needs closer attention from research and policy on how such local institutions can play their roles effectively and on the extent to which they can substitute direct interventions by government organizations and NGOs in soil and water conservation in Rwanda.

The three-stage analysis of the adoption of bench terraces in Chapter 6 showed that the future adoption of bench terraces in the highlands of Rwanda depends significantly on farmers' capacity to invest in complementary materials (e.g. lime, improved seeds, and fertilizers) and labour inputs. Most of terraces constructed in the past were developed within the context of project and policy support. Now subsidies used to construct these terraces are reduced or even non-existent in some places. The question remains whether an average farmer will be able to continue to use existing terraces and whether they will be able to construct new terraces on plots that need terraces? This is a long-term soil conservation issue.

The thesis argued that farmers are willing to use and add new bench terraces. This will be possible if farmers' financial capacity to invest in terraces is enhanced. The labour costs for terrace construction constitute a major part of investments in terraces. There is evidence from this thesis that farmers can still address these labour costs by collective actions fostered through social arrangements, their organizations, and by government policies that promote collectiveness (see Chapters 3 and 5). The main challenge ahead remains the effective use of developed terraces. Improving access to input credit would be an alternative option to empower farmers to use their terraced lands. On the other hand, lack of immediate financial returns from terraces explains less attractive bank investments in soil conservation. This is not unique to Rwanda but applies to other places as well. Again, banks that were created for the purpose of rural and agricultural development, such as *Banque Populaire*, are serving more other interests than those primarily meant for.

This study's findings pointed to an alternative source of credits, what farmers call '*Ikimina*', through which they lend and borrow money from each other. This prevents them from going to the bank or local money lenders who charge high interests. This farmer arrangement allows them to pay for inputs and other services. Then honesty, *ubunyangamugayo* or *ubupfura*, and the 'mutual assistance spirit', *umutima wo gufashanya'*, are collaterals. An alternative strategy would be to improve and support these farmer-based institutions in order for them to access credits to supply material inputs. If a better policy option is possible, then this can help to address the direct role of the state in soil conservation on private lands in the future. Also, farmers will gain confidence and react responsibly towards soil erosion conservation and overall agricultural development in Rwanda.

Findings of this study also disclosed that, due to limited land sizes, there is a potential risk of terracing very steep plots that are inappropriate for terracing. Again, the existing land holdings are still under registration to secure formal land rights. Private land rights are regarded as favourable for land markets and for efficient investments in land. Yet, there is limited evidence from the literature that private land rights are conducive to investments in soil and water conservation measures in other developing countries. The land consolidation policy, if successful, can allow large-scale investments in land use and management. However, this is constrained by the dispersed nature of settlements, which, in turn, has been for long time a development challenge in Rwanda.

In all, the task is more difficult than finding a proper policy for soil and water conservation alone. Other development challenges are exigent. Increased investments in other off-farm agriculture-related activities (such as agri-enterprises) in rural areas could be a long-term exit option to addressing some of the challenges facing agriculture development in Rwanda. This is likely to reduce the number of dependents and the pressure on land, but also to create markets for agricultural products resulting in the remaining farmers being well off. However, further investigation beyond this thesis is needed. Finally, investments are needed to foster education, which in turn can lead to the creation of other economic activities that may assist the agricultural sector towards the overall development of Rwanda in the long run.

7.5 Future research

This thesis has contributed to the understanding of the complexity of soil erosion problems in Rwanda. The focus was on how farmers and a variety of institutions affect the adoption and effectiveness of soil and water conservation measures in Rwanda. However, there are areas not addressed by this thesis that would be useful to be addressed by future research in soil and water conservation in Rwanda.

- To establish better knowledge of the existing indigenous soil and water conservation practices, as these can guide alternative and less-costly SWC measures in Rwanda.
- Further investigation at the macro level is needed to show how farmers are learning from and partly share emergent agricultural and development policy processes in Rwanda.
- Research by geologists and/or the soil scientists is needed to inform about physical and chemical micro-realities, such as variability of soil particles on terraced plots compared to plots with no terraces, in order to predict long-term effects (in terms of soil and water) of ongoing terrace construction in many parts of Rwanda
- An Economic and Social Cost–Benefit Analysis of bench terraces to determine costs and benefits of bench terraces beyond the private perspective in Rwanda.
- More research on the governance of farmer organizations and other local-level institutions to indicate how they can play effective roles to complement government and non-government interventions in rural development and land conservation in Rwanda

APPENDICES

Appendix 1.1 Sampling Maps

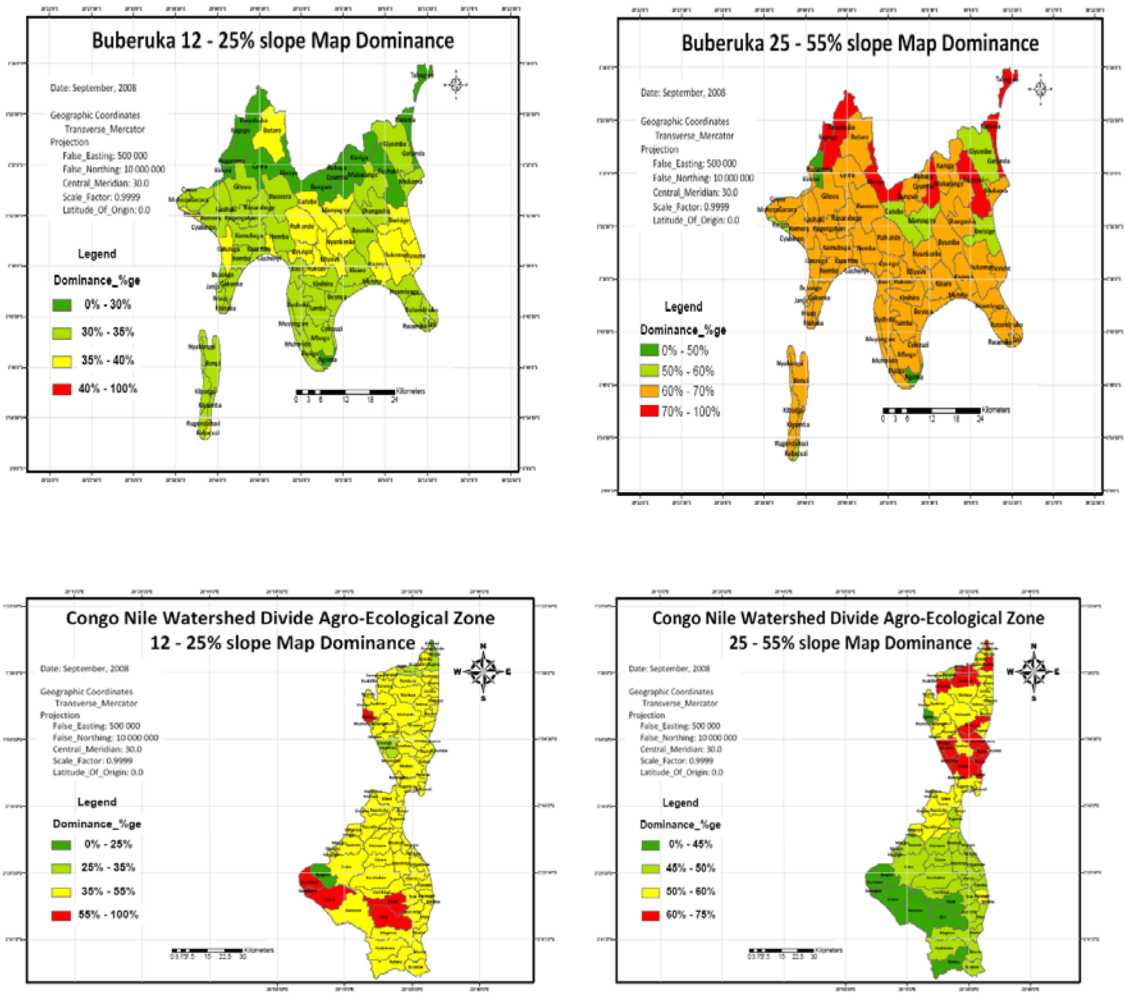
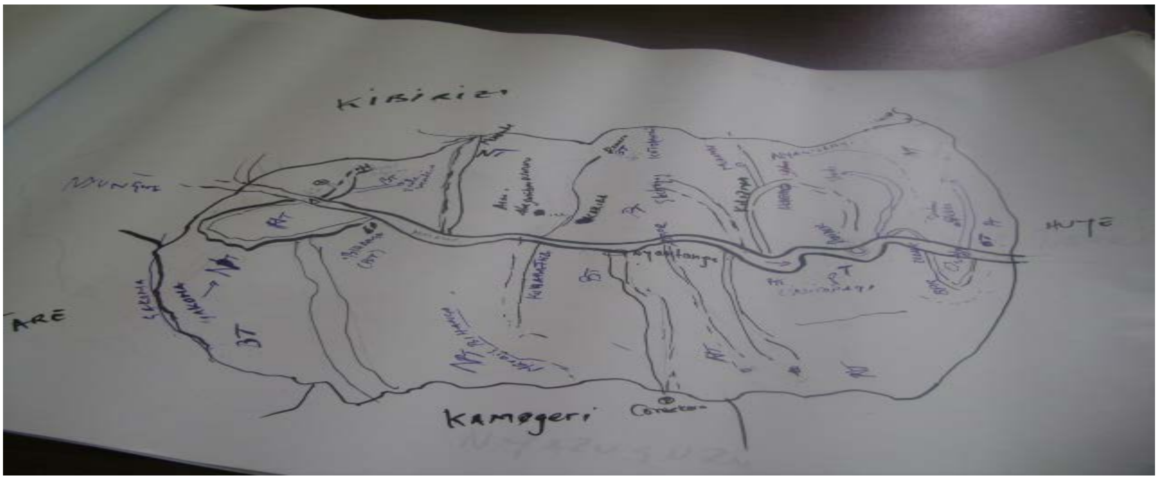


Figure 1.1 Maps for Slope dominance in the research area (© *Bizoza*, January 2009).

Appendix 1.2



Kageyo Sector

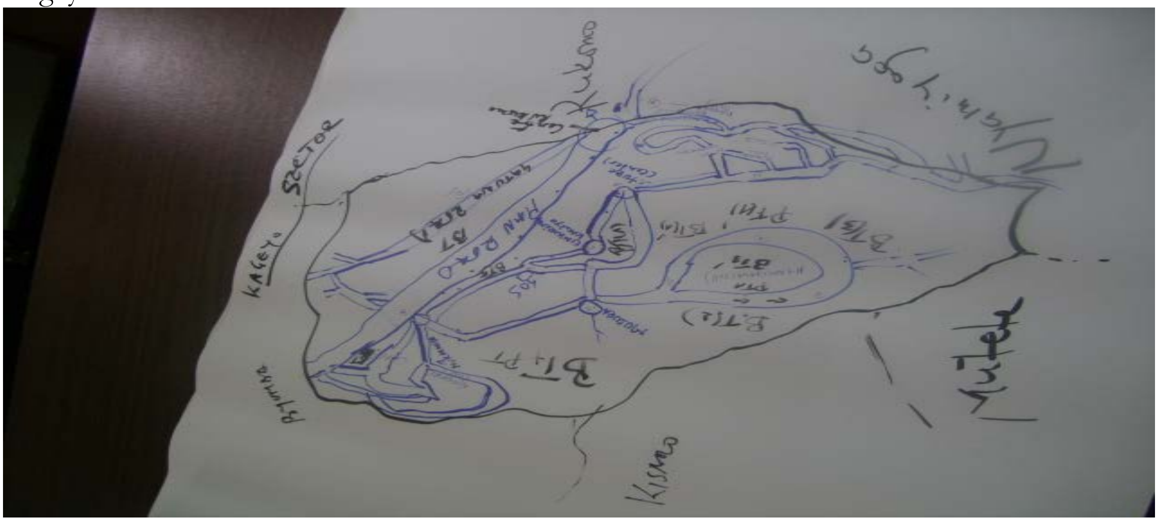
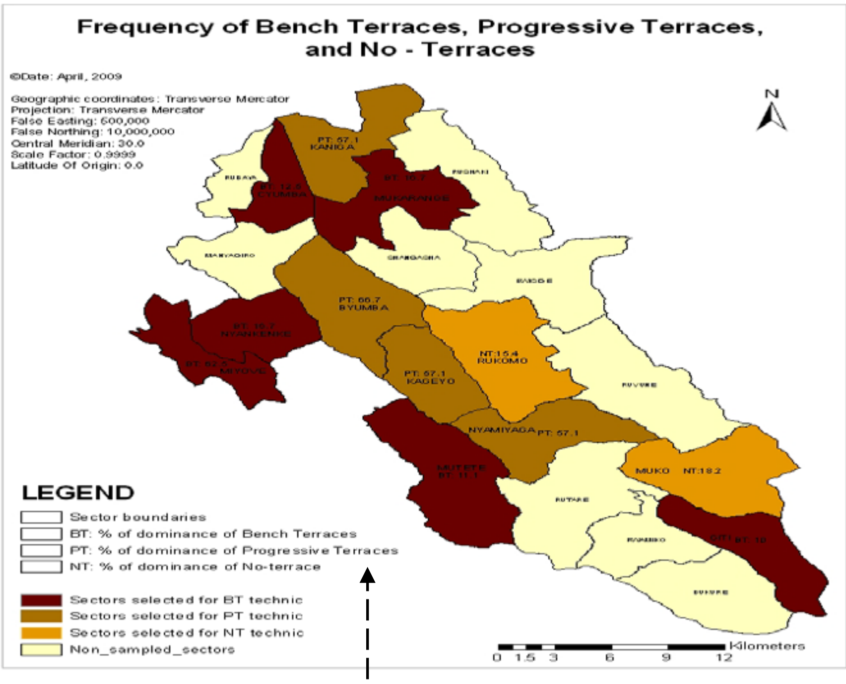
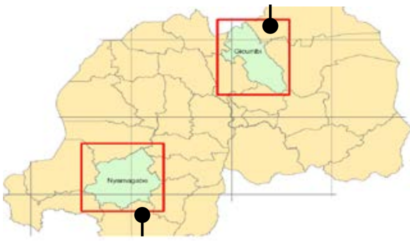


Figure 1.2: Farmer based mapping of terraces dominance (BT, PT and NT) in sample sectors (Kibirizi and Kageyo), South and Northern Rwanda.

Appendix 1.3.
Northern Province _Gicumbi District (BHLZ)





Rwanda

Southern Province _Nyamagabe District (CNWZ)

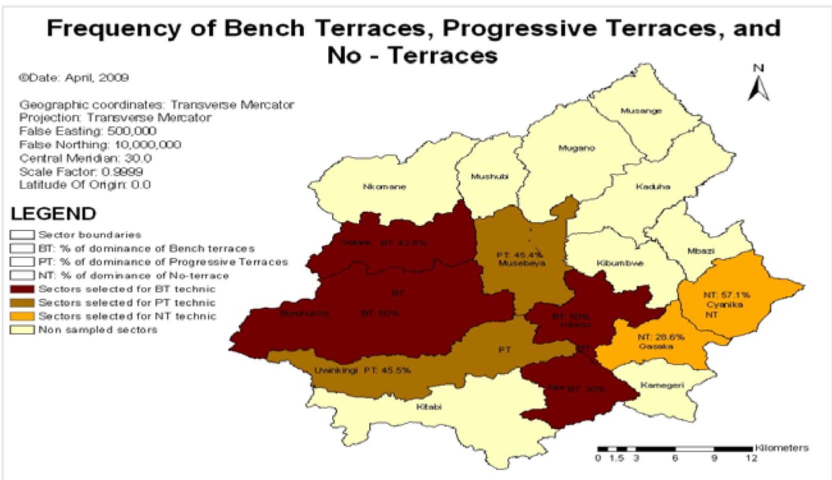


Figure 1.3: Research sites and their location vis-à-vis Rwanda

Appendix 2: Sources of agricultural advice

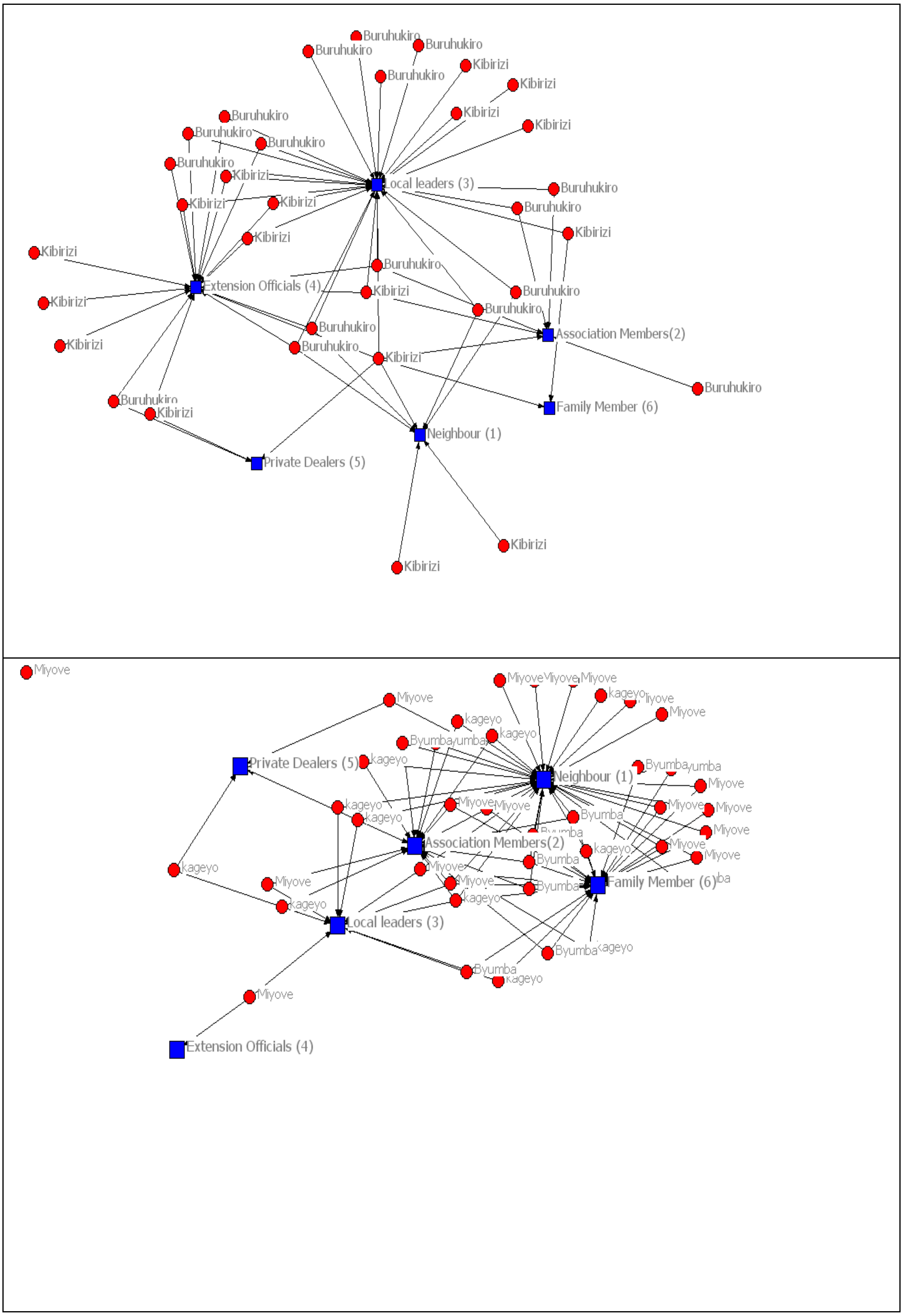


Figure 5.1.Source of agricultural advise for farmers in nearest Sectors

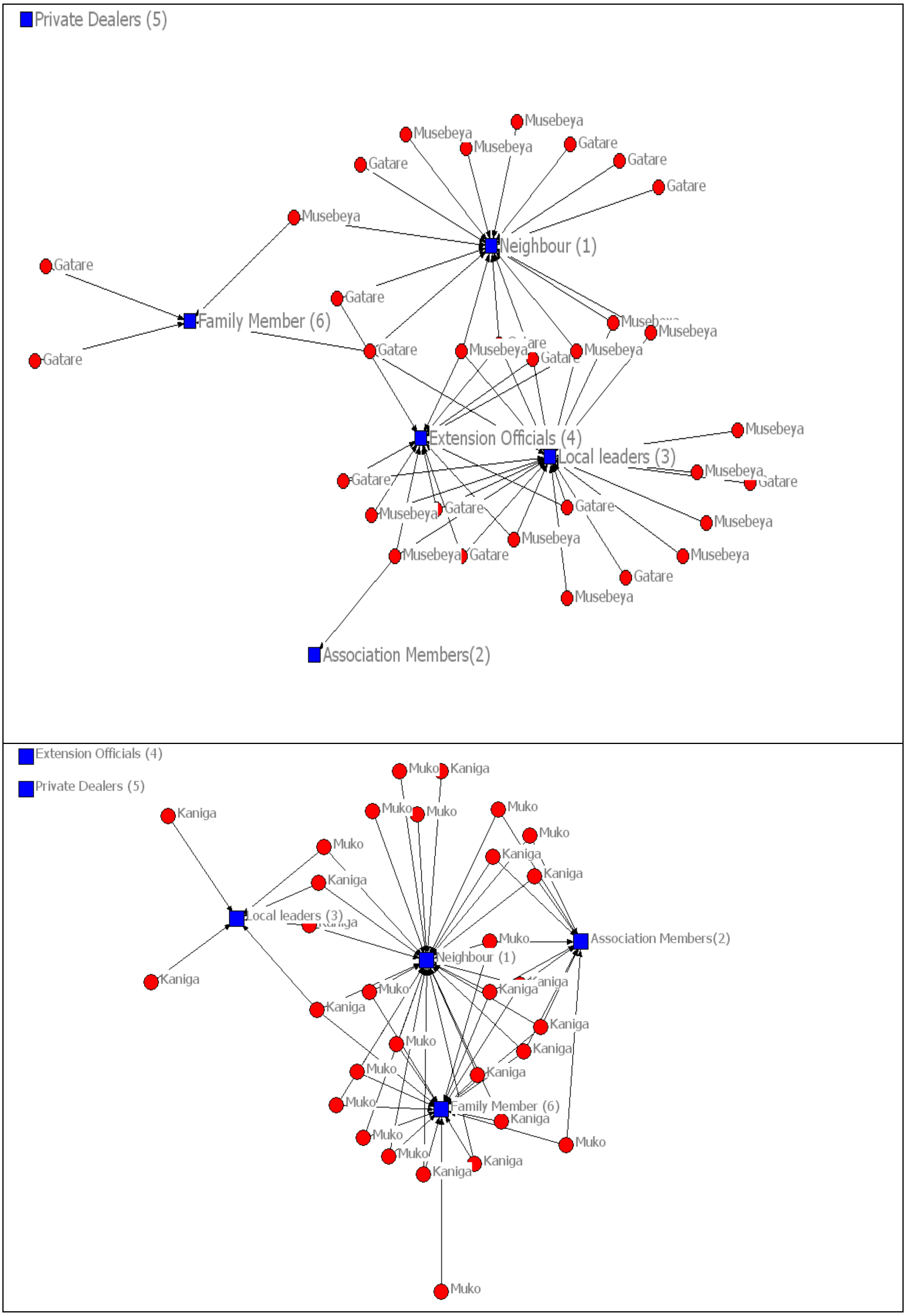


Figure 5.2. Source of agricultural advice for farmers in remote sectors

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SUMMARY

This thesis is about soil and water conservation (SWC) issues in Rwanda. Land conservation in Rwanda started in the early twentieth century, in the same era as in many African countries. Despite tremendous efforts in soil erosion control by the state and other development agents, it remains a major development challenge in Rwandan agriculture. Bench terracing is the main SWC technique to receive much attention from various interventions in land conservation since the 1970s. This study 'unpacks' the adoption process of bench terraces that has become popular in agriculture development in Rwanda and elsewhere in the developing world. Hence, it is possible to increase the understanding of the complexity of land degradation problem and how farmers affect the adoption and effectiveness of SWC measures in rural Rwanda.

This research contributes to an understanding of this issue from an institutional and socio-economic perspective. It aims to: (i) provide a historical account of SWC measures used from the pre-colonial to the independent state in Rwanda; (ii) assess how farmers participate in soil conservation and how state–farmer relationships affect SWC strategies; (iii) investigate under which socio-economic conditions bench terraces are financially viable; and (iv) explore which factors explain current and future adoption of terraces, with closer attention to the potential effects of local institutions and farmers' capacity to invest in bench terraces in Northern and Southern Rwanda.

Chapter 2 provides an account of soil erosion control in Rwanda in a historical perspective. Findings indicate that the approach used to introduce SWC techniques in Rwanda has shifted over time from top-down to somewhat participatory, in tune with the major developmental and political changes that occurred before and after the independent state. Some of the techniques introduced during the colonial period were abandoned by farmers because top-down approaches led to coerced SWC measures with little space for farmers to learn, appreciate, and materialize the benefits of adopting soil conservation. Throughout the history of soil conservation in Rwanda, population growth and reduced soil fertility have been major driving factors. However, the focus was more on soil erosion control rather than joining this to control of population growth, which, in turn, led to small and fragmented per capita land holdings (often less than 1 ha). Yet, a 'big family' on a fixed piece of land are two conflicting factors and remain key challenges for land conservation and management in Rwanda.

In Chapter 3, information is used from focus-group discussions with members of small-scale associations to assess how farmers participate in soil conservation and how state–farmer relationships affect SWC strategies in Rwanda. The argument guiding this analysis is that bench terraces can not be understood in isolation from their social and institutional environments. Farmers' perceptions of and participation in SWC can be understood in the context of state–farmer relationships. It is found that farmers play a marginal role in the design and implementation of SWC measures. They only participate in terms of consultation and self-mobilization to supply labour, time and sometimes land for terrace construction. This affects the ownership and, hence, the sustainability of established SWC structures.

From a private perspective, bench terraces do not seem to be a better option. They require external support and skills from the experts (development officials) as well as new forms of organization. Findings in this thesis reveal different forms of institutional

arrangements (policies) initiated by the government to promote collective action and self-reliance mentality in soil conservation. At the same time, 'local' institutions such as collective action and 'mutual assistance' or reciprocity evolve from farmers' organizations and other social arrangements. These enable farmers to tackle some of the farming constraints, including labour for terrace construction, through co-operation in collective action. However, the commoditization of labour as a result of food and cash incentives used to induce adoption of bench terraces by SWC projects may have distorted a real sense of collective action found in traditional Rwandan society. In addition, most terraces constructed under such incentives are perceived by farmers to be not technically effective. This will result in more soil erosion and soil acidity, creating higher maintenance and user costs for future generations of soil conservation.

In Chapter 4, a plot level financial cost-benefit analysis was conducted to show under which socio-economic conditions bench terraces are financially viable. A subsample of 101 plots of 82 households was selected randomly out of the total sample of 907 plots. The assumption is that terraces may reduce soil erosion and increase production but they should also provide sufficient financial gains. The analysis shows that the adoption of bench terraces in the research area is not sufficiently explained by its profitability. An initial analysis involving farmers' estimates and market prices shows that bench terracing is hardly profitable. Labour and manure represent the major part of operating costs. Subsequent analysis introducing 50% opportunity costs of market prices for labour and manure shows that bench terraces are profitable. Therefore, sample bench terraces are likely to be profitable when these costs are reduced or when terraced plots are used more intensively by farmers.

The effectiveness of bench terraces was also assessed based on farmers' classification of soil types. Successful construction of bench terraces requires detailed analysis of soil suitability. Both bench terraces and progressive terraces are established on *Urunombe* soils (Nitosols high in loam and clay). In some situations, these low permeable soils are sensitive to *Nyamurigita* soil erosion type, which leads to rotational land slides and the destruction of terraced land. This reflects the need for technical guidance to lower future user costs of bench terraces.

Chapters 5 and 6 are concerned with the role of local institutions and farmers' capacity to invest in terraces. Information was used that was collected during the survey conducted in Northern and Southern Rwanda among 301 households who also provided information on their 907 plots. The analysis in Chapter 5 is closely related to Chapter 3. The focus is on the effect of local institutions on the adoption of bench and progressive terraces. The findings showed that social capital, measured as trust and co-operation in collective action, is conducive to bench terrace adoption. None of the institutional variables identified are estimated important in explaining adoption of progressive terraces. This implies that some social and institutional arrangements are required more for establishing bench terraces than for progressive ones. Social capital presents itself as alternative asset(s) for further investments in bench terraces in rural Rwanda.

In Chapter 6, a recursive model of current and future adoption decisions of bench terraces is evaluated, including farmers' capacity to invest in complementary inputs. It is hypothesized whether farmers are willing to uptake more or new terraces in their respective villages. Results sustain that future adoption of bench terraces proxied with farmers' willingness to adopt bench terraces depends significantly on farmers' capacity to invest in inputs, prior adoption of bench terraces, and other factors. Improving farmers' income should receive particular attention in future interventions in land conservation to ensure not only adoption but also maintenance and continued use of bench terraces by farmers in the highlands of Rwanda.

Chapter 7 presents some conclusions and policy options based on results detailed in Chapters 2 to 6. In this Chapter, the specific research questions are revisited to offer key results and their implications; they are followed by policy and research options.

Overall, the thesis provides an explanation to why some previously constructed terraces are not maintained and used effectively by farmers in Rwanda. Throughout the history of soil and water conservation, farmers have been forced to adopt SWC measures, generally in the colonial period. Bottom-up approaches promoted by development agents, including the government in post colonial Rwanda, are not sufficiently effective to ensure full participation of farmers in the design and implementation of SWC measures. Despite their role in soil conservation, local institutions are not sufficiently empowered to ensure interdependency, which, in turn, may guarantee long-term sustainability of established SWC measures. Financial returns from established bench terraces are still lower to allow additional investments by farmers themselves in the maintenance of existing terraces or the construction of new ones. Farmers' inabilities to secure additional inputs required by terraces after construction may restrain the take-up of more terracing in the study area. Further interventions should focus on improving institutional and socio-economic conditions before high cost-based investments similar to bench terraces are introduced within the existing farming systems. The incompatibility of bench terracing with prevailing institutional and socio-economic conditions is likely to facilitate more soil erosion.

Future research should focus on physical and chemical micro-realities to predict long-term effects of ongoing terrace construction. Assessment of externalities of or downstream bench terraces could inform the potential role of local institutions. How they can supplement or substitute direct interventions by the government and NGOs in soil conservation constitutes interest for the policy and research. Furthermore, advanced research is needed to indicate the extent to which bench terraces can (or cannot) be renewed or replaced by other soil conservation techniques. This needs yet further investigation to benefit future generations of soil and water conservation in Rwanda.

SAMENVATTING

Dit proefschrift gaat over bodem- en waterconserveringsissues (BWC) in Rwanda. Begin twintigste eeuw startte landconservering in Rwanda. Ondanks de enorme inspanningen van de staat en andere ontwikkelingsinstanties in de beheersing van bodemerosie, blijft het een van de grote uitdagingen van de Rwandese landbouw. De voornaamste BWC-techniek is 'bench teraccing' (terras landbouw)en speelt een rol in verschillende interventies op het gebeid van land conservering sinds de jaren '70. Deze studie ontleedt het adoptieproces van 'bench terraces' dat populair is geworden in de ontwikkeling van de landbouw in Rwanda en . Hierdoor krijgen we meer inzicht in de complexiteit van het probleem van landdegradatie en hoe boeren de adoptie en effectiviteit van BWC maatregelen beïnvloeden in Rwanda.

Dit onderzoek draagt bij aan een beter inzicht in dit onderwerp vanuit een institutioneel en sociaaleconomisch perspectief. Het beoogt;(i) een historisch overzicht te geven van de BWC maatregelen gebruikt vanaf de pre-koloniale tot de onafhankelijkheidsperiode in Rwanda, (ii) te bekijken hoe boeren participeren in bodemconservering en hoe de relatie tussen staat en boer de BWC strategieën beïnvloedt, (iii) te onderzoeken onder welke sociaaleconomische condities 'bench terracing' financieel levensvatbaar is; en (iv) het verkennen van de factoren die de huidige en toekomstige adoptie van terrassen verklaren, met speciale aandacht voor de mogelijke effecten op lokale instituties en op de capaciteiten van boeren om te investeren in 'bench terracing' in het Noorden en Zuiden van Rwanda.

Hoofdstuk 2 geeft een historisch overzicht van bodemerosie beheersing in Rwanda. Bevindingen wijzen op een verschuiving in de gebruikte benadering om BWC technieken te introduceren in Rwanda, van to-down naar een meer participatieve benadering, in lijn met de grote ontwikkelingen en politieke veranderingen in Rwanda voor en na de onafhankelijkheid. Sommige technieken die werden geïntroduceerd gedurende de koloniale periode zijn door boeren opgegeven mede doordat de top-down benaderingen leidden tot dwingende BWC maatregelen die weinig ruimte overlieten aan boeren om de voordelen van bodem conservering te leren, te waarderen, en meet te experimenteren. Door de geschiedenis heen zijn groeiende populatie en afnemende bodemvruchtbaarheid zijn de grote drijvende krachten geweest achter bodemconservering in Rwanda. De focus lag op de controle van landerosie zonder dat dit werd gecomplementeerd met een beperking van de bevolkingsgroei, wat daardoor weer leidde tot kleine en gefragmenteerde land holdings per hoofd van de bevolking (vaak minder dan 1 ha).

In hoofdstuk 3 wordt informatie van focus-groep discussies met leden van kleinschalige associaties gebruikt om te bepalen hoe boeren participeren in bodemconservering en hoe de relatie tussen de staat en de boer de BWC strategieën in Rwanda beïnvloedt. Het argument luidt dat 'bench terraces' niet kunnen worden begrepen los van hun sociaal institutionele omgeving. De percepties van boeren en hun participatie in BWC kan worden begrepen in de context van staat-boer relaties. Er is geconstateerd dat boeren een marginale rol spelen in het ontwikkelingen en implementeren van BWC maatregelen. Zij participeren alleen in termen van consultatie en zelf-mobilisatie bij het leveren van arbeid, tijd en soms land voor de bouw van terrassen. Dit beïnvloedt ownership" en, dus, de duurzaamheid van de BWC structuren.

Vanuit een individueel perspectief lijken 'bench terraces' niet een betere optie. Zij behoeven externe ondersteuning en vaardigheden van expert (ontwikkelingsdeskundigen) zowel als nieuwe vormen van organisatie. Bevindingen in dit proefschrift tonen verschillende vormen van institutionele arrangementen (beleid) geïnitieerd door de overheid om collectieve actie en een mentaliteit van vertrouwen in bodemconservering te promoten. Tegelijkertijd ontvouwen zich 'lokale' instituties zoals collectieve actie en 'gelijke hulp' of reciprociteit vanuit boeren organisaties en andere sociale arrangementen. Deze geven boeren de mogelijkheid om enkele landbouwkundige beperkingen aan te pakken, inclusief arbeid voor terrasbouw, door samenwerking. Echter, de commoditisatie van arbeid als gevolg van de prikkels, voedsel en geld, die zijn gebruikt om aan te sporen tot de adoptie van 'bench terraces' door BWC projecten kunnen het daadwerkelijke gevoel van collectieve actie aanwezig in de traditionele Rwandese maatschappij hebben aangetast. Daarbij, de meeste terrassen die met deze prikkels zijn bewerkstelligd, worden door boeren niet als technisch effectief gezien. Dit zal resulteren in meer bodemerosie en bodemverzuring, wat leidt tot meer onderhoud en hogere gebruikskosten voor komende generaties.

Hoofdstuk 4 laat met behulp van gegevens verkregen op het veld niveau met behulp van een financiële kosten-baten analyse zien onder welke sociaal-economische condities 'bench terraces' financieel levensvatbaar is. Een steekproef van 101 plots van 82 huishouden is willekeurig geselecteerd uit een totale groep van 907 plots. De aanname is dat terrasbouw de bodemerosie kan verminderen en de productie kan laten toenemen. Maar terrasbouw moet ook voldoende financiële opbrengsten opleveren. De analyse toont dat de adoptie van terrasbouw in het onderzoeksgebied niet voldoende verklaard wordt vanuit winstoogmerk. Een initiële analyse van de schattingen van boeren en marktprijzen laat zien dat 'bench terracing' nauwelijks winstgevend is. Arbeid en dierlijke mest vertegenwoordigen het overgrote deel van de vaste kosten. Om die reden zijn voorbeeld 'bench terraces' zeer waarschijnlijk winstgevend omdat de deze kosten zijn gereduceerd of omdat de plots intensiever worden gebruikt door boeren.

De effectiviteit van 'bench terraces' is ook beoordeeld op basis van de classificatie van bodemtypen door boeren. Succesvolle bouw van 'bench terraces' vraagt gedetailleerde analyse van bodemgeschiktheid. Zowel 'bench terraces' als progressieve 'terraces' zijn gebouwd op *Urunombe* bodems (Nitosols zijn rijk aan leem en klei). In sommige situaties zijn deze slecht doorlaatbare bodems gevoelig voor het type *Nyamurigita* bodemerosie, wat leidt tot roterend landverschuiving en de destructie van 'terraced' land. Dit reflecteert de behoeften voor technische raadgeving om de toekomstige gebruikskosten naar beneden te brengen.

Hoofdstuk 5 en 6 hebben betrekking op de rol van lokale instituties en de boerencapaciteit om te investeren in terrassen. De informatie die is gebruikt is verzameld gedurende een survey in Noord en Zuid Rwanda onder 301 huishoudens die ook informatie gaven over hun 907 plots. De focus van hoofdstuk 5 ligt op het effect van lokale instituties op de adoptie van bench en progressive terrassen. De bevindingen tonen aan dat sociaal kapitaal, gemeten als vertrouwen en samenwerking in collectie actie, leidend is bij de adoptie van bench terraces. Geen van de geïdentificeerdeinstitutionele variabelen blijken de adoptie van bench terraces te kunnen verklaren. Dit betekent dat sommige sociale en institutionele arrangementen belangrijker zijn voor bench terraces dan voor progressieve terrassen. Sociaal kapitaal is een alternatieve hulbronnen voor toekomstige investeringen in 'bench terraces' in Rwanda.

Hoofdstuk 6 evalueert een recursief model van huidige en toekomstige adoptiebeslissingen met betrekking tot bench terraces inclusief de capaciteit van boeren om te investeren in complementaire inputs. Het bestudeert of boeren bereid zijn om meer of nieuwe terrassen op te nemen in hun dorpen. Resultaten steunen de toekomstige adoptie van 'bench terraces' gemeten als de bereidwilligheid van boeren om 'bench terreces' te adopteren, hangt significant samen met de capaciteit van boeren om te kunnen investeren in inputs, vorige adoptie van bench terraces en andere factoren. Het verbeteren van de inkomsten van boeren zou nadrukkelijk de aandacht moeten krijgen in toekomstige interventies in landconservering om niet alleen adoptie maar ook onderhoud en voortgezet gebruik van 'bench terraces' door boeren in de hooglanden van Rwandate waarborgen.

Hoofdstuk 7 gaat terug naar de onderzoeksvragen en presenteert enkele conclusies en beleidsopties.

CURRICULUM VITAE

Alfred Runezerwa Bizoza was born in South Kivu, Democratic Republic of Congo (former Zaïre), 23 December 1975. He received his primary and secondary education in the Great Lake Region in East Africa: DRC, Burundi, and Rwanda. In 1995, he joined Rubengera high school in the former Kibuye province (Rwanda) to complete his secondary education from where he obtained A2-level certificate in Biology and Chemistry.
In 1996, he enrolled for a BSc degree in Economics at the National University of Rwanda (NUR), which he obtained with Distinction during the 2000–2001 academic year. He was employed by World Vision International Rwanda for two years (November 2000–November 2002).

He rejoined the National University of Rwanda as an Assistant Lecturer in the Department of Economics. In 2004, he received a scholarship from the Capacity Building Programme of the World Bank for an MSc and graduated in 2005 in the Department of Agricultural Economics, School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal, South Africa. Later, he was transferred to the Faculty of Agriculture to start the Department of Agricultural Economics, of which he was nominated as the first Head of Department in 2006.

Currently he is a Lecturer in Agricultural Economics at the Faculty of Agriculture, NUR. In this capacity, besides teaching assignments, he has also published a number of papers. He has supervised both undergraduate and postgraduate students for their final reports and has worked sometimes as co-examiner of MSc reports at NUR and WUR. He has been appointed as member and sometimes head of different task forces within or outside the National University of Rwanda. Since 2006, he is involved as a research partner in the Challenge Program of the Forum for Agricultural Research in Africa (FARA), Lake Kivu Pilot Learning Site.

He joined Wageningen University, Netherlands, as PhD candidate in January 2007. His PhD focused on an institutional economic analysis of bench terraces in the highlands of Rwanda. While doing his PhD, he also presented different papers in national and international conferences. In 2009, he worked as a visiting scholar at the International Institute of Agriculture (IIA), Michigan State University, USA.

As a specialist in the institutional economics of land conservation, he will continue to apply the knowledge gained by teaching and by conducting research in Rwanda and elsewhere his skills will be needed.

He is gladly married to Justine Nyirabaruta and they are currently blessed with two sons and one daughter: David, Divine and Joshua.

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Wageningen School of Social Sciences

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Description	Institute/Department	Year	Credits
Courses:			
CERES Orientation Course	CERES Utrecht University	2007	5
Planning, monitoring, evaluation & Impact assessment of R& D investments in Agriculture	Haramaya University, Ethiopia	2006	3
Rural Development Projects and Programmes in Developing Countries	RDS	2007	4
Techniques for writing and presenting a scientific paper	Wageningen and National University of Rwanda (NUR)	2007	1.2
Advanced Econometrics	AEP/ MG3S	2008	6
Analysis of Land Dynamics and sustainable development in an interdisciplinary perspective	PE& RC, SENSE, CERES and MG3S (in Kenya)	2009	4
PhD research Proposal	CERES	2007	6
Presentations, conferences, seminars or workshops			
A historical overview of soil erosion controls in Rwanda (International workshop)	Wur and NUR in Rwanda	2008	2
Challenges and opportunities of Social Science research Development in Rwanda	National University of Rwanda	2008	2
Costs and Benefits of bench terraces in Rwanda (Visiting scholar)	Michigan State University , USA	2009	6
The impact of adoption of improved potato packaging technology on income of small scale farmers in Gataraga Sector , Northern Rwanda	Forum for Agricultural Research in Africa (FARA) / Ghana	2010	1
Total			**40.2**