Chapter 26
Institutions and the Adoption of Technologies: Bench Terraces in Rwanda

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Abstract Local institutions shape the adoption of soil and water conservation (SWC) technologies. Various techniques for SWC are used once adopted by farmers such as bench terraces and hedges. Some farmers are reluctant for the adoption to a number of factors including institutions in their diverse forms. The paper specifies 'soft' and 'hard' social capitals, among other factors, to estimate their impacts on adoption of bench and progressive terraces in rural Rwanda- dominant forms of SWC in the history of land conservation in Rwanda. Data used for this study were collected among 301 households who also provided information on 907 plots located in the Northern and Southern Provinces in Rwanda. Sample households were selected using a stratified random sampling procedure. The results substantiate that some forms of social capital, i.e. trust and co-operation in collective labour, matter in the adoption process of bench terraces in Rwanda. These findings postulate 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. Findings 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. Therefore, the results of this study help to guide both research into and policy on how local institutions can play better roles and the extent to which the institutions can substitute direct interventions by NGOs and policy-makers in soil and water conservation in Rwanda.

Keywords Institutions • Social capital • Bench terraces • Rwanda • Soil and water conservation (SWC)

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Introduction

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 (Tenge et al. 2004; Pretty and Shah 1997; Shiferaw and Holden 1998).

Previous studies identify factors that drive adoption of agricultural technologies. These vary from bio-physical, socioeconomic, and institutional factors (Feder et al. 1985; Knowler and Bradshaw 2007; Rezvanfar et al. 2009; Graaff et al. 2008). However, the analysis of what drives or impedes agricultural technology adoption focused more on geographical conditions, people's economic and demographic characteristics, less on the role of local institutions (Knowler and Bradshaw 2007). 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).

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.

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.

Soil and Water Conservation and Institutions in Rwanda

Institutions and Soil and Water Conservation

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 al. 2004). 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.

Land tenure security and social capital are both institutions are part of institutions (hard and soft) that affect the investment in soil and water conservation in many parts of Africa and Rwanda (Tenge et al. 2004; Shiferaw and Holden 1998). 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 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

(Krishna 2004). 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 (Isham 2002; Nyangena 2008). 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 (Krishna 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 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 such as those in Sub-Saharan African where formal institutions are of relatively weak.

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 Machakos, 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 (Sidibé 2005). 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).

Overview of Bench Terracing in Rwanda

Bench terracing was 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 7 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).

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 (Bunch 1999: 216). 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 (Newbury and Newbury 2000).

Despite efforts and progress made, the soil erosion control remains important. The 2008 National Agriculture Survey (NAS) showed that 62 % of the cultivable area in Rwanda (an estimate of 1.3 million ha) is protected by anti-erosive measures. Furthermore, 4 % of the protected area is provided by bench (radical) terraces compared to 69 % by anti-erosion ditches of which progressive terraces are formed. Kannan et al. (2010) indicate that 93 % 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 such a technology. Unless measures to use terraced plots effectively are provided by governmental organizations and NGOs, farmers are rational not to construct terraces on small plots, much of which they depend on for their livelihoods. 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 (2010) showed 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.

Research Methods

The aim here is to analyse the impact of various local institutions on the adoption of bench terraces in rural Rwanda. The hypothesis that we want to test is whether 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 was carried out in areas (sectors) that cover major parts of the Gicumbi (Northern) and Nyamagabe (Southern) Districts of Rwanda.

The survey respondents were obtained from Buberuka Highland and Congo Crete Nil Watershed agro-ecological zones located in the Northern and Southern Rwanda, respectively. These two zones have a similar topography and received relatively more soil and water conservation interventions due partly to higher erosion risks compared to other zones in Rwanda. A stratified and random sampling procedure was used to obtain respondents from areas that are suitable for bench terraces (25–55 % slope level) and those appropriate for progressive terraces (12–25 % slope level). 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 for SWC such as bench and progressive terraces.

The data collected allowed for testing the impact of social capital on the adoption of terraces, controlling for: plot-, farm- and household-level characteristics, and sector-level. 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 (Table 26.1).

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 to an organization are two indicators often used for empirical measurement of social capital (Glaeser et al. 2002; Krishna 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? All these stakeholders inter-relate with farmers in the adoption process of new technologies. More specifically, they constitute channels of extension services provided by development officials and hence they are expected to induce farmers adopt or disadopt depending on how they trust them. Trust was coded on a four-point scale, ranging from 1 ('not at all') to 4 ('very much').

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 to 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).

Table 26.1 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 ha)	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 a.s.l)	Average altitude of the sub-catchment/Village	301	2,103	163.34
Farm size	Total farm sizes in Ares (1 are = 0.01 ha)	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	301	0.31	0.46

(continued)

Table 26.1 (continued)

Explanatory variables	Description	Obs.	Mean	SD
	visit/ extension meeting and 0 if otherwise			
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	68,640	45,575
District	Equals 1 if the plot (family) is located in the North and 0, if the Southern region	301	0.55	0.49
Dependent 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

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 26.1 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 Eq. 26.1. 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).

$$Y_{ik} = \alpha + \beta_1 SC_{1i} + \beta_2 SC_{2i} + \beta_3 TS_i + \gamma_1 X_k + \gamma_2 W_i + \gamma_3 Z_c + \varepsilon_{ik} \tag{26.1}$$

Where i indexes the household, k stands for the plot, while c denotes sector-level variables. Y_{ik} stands for dependent variables BTA and 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. Another option is to compute trust and association membership scores at household level using factor analysis (Narayan and 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. The DWH test for endogeneity of tenure security (TS) and association membership resulted in a strong acceptance of the null 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.

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 26.2 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 explanation 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 (about 65 %) used in the analysis from random sectors that did not receive much support from World Vision for bench terrace construction.

Table 26.2 Probit regression of adoption of bench terraces with robust standard errors (clustered at household level)

	Bench terrace adoption (BTA)	
Variable	Coefficient (robust Std. Dev)	Marginal effect
Institutional factors (SC)		
Trust	0.408 (0.132)***	0.141
Association membership	−0.182 (0.126)	−0.061
Collective action	2.136 (0.297)***	0.678
Tenure security (TS)	0.104 (0.137)	0.035
Plot Controls (X)		
Steep Slope	0.489 (0.169)***	0.178
Gentle Slope	0.339 (0.133)**	0.115
Plot size (Log)	0.157 (0.052)***	0.054
Inheritance	−0.223 (0.104)**	−0.077
Distance	−0.021 (0.004)***	−0.007
Farm and household level variables (W)		
Altitude (m a.s.l)	0.002 (0.000)***	0.0007
Farm size	−0.104 (0.068)	−0.036
Higher erosion	−0.648 (0.151)***	−0.193
Moderate erosion	−0170 (0.120)	−0.057
Female head	−0.534 (0.121)	−0.052
Age	−0.013 (0.023)	−0.004
Age (squared)	0.0001 (0.000)	0.00002
Formal education	0.001 (0.019)	−0.0004
Informal education	0.315 (0.133)**	0.111
Family size	0.058 (0.034)*	0.020
Total Livestock Unit (TLU)	0.013 (0.056)	0.004
Sector-level variables (Z)		
Programme Support	0.105 (0.129)	0.036
Average sector-level income	4.07E-06 (1.24E-06)***	1.42E-06
District	0.577 (0.138)***	0.190
Constant	−6.630 (1.163)***	
Regression diagnostics		
Log Likelihood	−430.754	
Chi-square (23)	193.49	
Probability > Chi-square	0.0000	
Pseudo *R*-square	0.2494	
Predicted Probability at mean	0.294	
Sample size (*n*)	906	

$*P < 0.1$; $**P < 0.05$; $***P < 0.01$

Some farm and household-level variables (W) correlated with the adoption of bench terraces at different critical levels: altitude, high potential erosion, informal education, and family size. Farmers with plots located in mountainous catchment areas with high potential erosion were 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; Mbanga-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, the training they receive, and their contacts with extension officials.

Characteristics of the plot 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 were 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 discouraged 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 was from the homestead, the greater the transactions costs expected, especially when farmers relied on transporting residues and other inputs from their homesteads to the farms on their heads. 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.[1] Results from the T-test confirmed that terraced plots received 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

[1] 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).

reported that not all terraced plots were cultivated and that labour costs constituted 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 reported that 46 % of the households accessed their land through inheritance compared to 25 % 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 (ref). The government has initiated a process of land registration and the issuance of formal land rights. However, this may not be necessarily inducing 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.

The analysis on the effect of institutions on bench terrace adoption showed 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) was 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 onsite 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 showed that collective action in the form of labour pooling, another measure of SC_1, had 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 tedious task that is 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.

Surprisingly, the effect of structural social capital (SC_2), represented here by membership of farmers' associations, was zero. This outcome stands in contrast to other empirical findings from previous studies where membership of associations had 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) did not explain bench terrace adoption (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 Swinton 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 felt they had secure land tenure – these are people farming plots that they inherited from their fathers compared to farmers who had purchased plots (holding deeds) or who had 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. Therefore, 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.

Results of the progressive terrace adoption (PTA) are presented in Table 26.3. Only six of the variables used are significant 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 was not significant, which suggests that farmers in areas with higher than average incomes were likely to prefer BTA over PTA, under *ceteris paribus* conditions. Contrary to the outcomes of the analysis of BTA, programme support explained PTA (significant at the 5 % level). A possible reason could be the 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 correlated with PTA. These variables are estimated with their

Table 26.3 Probit regression of adoption of progressive terraces with robust standard errors (clustered at household level)

	Progressive terrace adoption (PTA)	
Variable	Coefficient (robust Std. Dev)	Marginal effect
Institutional factors (SC)		
Trust	−0.163 (0.122)	−0.052
Association membership	0.010 (0.121)	0.003
Collective action	−0.069 (0.232)	−0.021
Tenure security (TS)	0.118 (0.148)	0.037
Plot Controls (X)		
Steep Slope	−0.254 (0.143)*	−0.078
Gentle Slope	−0.055 (0.118)	−0.017
Plot size (Log)	0.164 (0.048)***	0.053
Inheritance	0.105 (0.097)	0.033
Distance	−0.009 (0.003)***	0.003
Farm and household level variables (W)		
Altitude (m a.s.l)	0.002 (0.0003)***	0.0007
Farm size	−0.095 (0.074)	−0.031
Higher erosion	0.193 (0.147)	0.065
Moderate erosion	0.189 (0.122)	0.062
Female head	0.171 (0.115)	0.0554
Age	−0.008 (0.025)	−0.003
Age (squared)	0.00007 (0.000)	0.00002
Formal education	−0.008 (0.017)	−0.002
Informal education	0.181 (0.121)	0.059
Family size	−0.028 (0.028)	−0.008
Total Livestock Unit (TLU)	−0.084 (0.054)	−0.027
Sector-level variables (Z)		
Programme Support	0.292 (0.132)**	0.095
Average sector-level income	−2.07E-06 (1.37E-06)	−6.70E-07
District	0.807 (0.141)***	0.244
Constant	−5.287 (0.994)***	
Regression diagnostics		
Log Likelihood	−485.904	
Chi-square (23)	116.04	
Probability > Chi-square	0.000	
Pseudo R-square	0.1007	
Predicted Probability at mean	0.258	
Sample size (n)	906	

$*P < 0.1$; $**P < 0.05$; $***P < 0.01$

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 nor tenure security explained adoption of 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 Ward 2001). Similar to the results in the analysis of BTA, there was no empirical evidence that association membership and land tenure security encouraged 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; Ahlerup et al. 2009).

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. For example, this case-study proves that about 10 % of smallholders abandon their terraced plots or fail to use them productively. 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. Therefore, government and NGOs need to allocate further investments in the consecutive use of established terraces than in the construction of new ones.

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. 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 could be reason why the effect of land tenure on the adoption of technology is found to be insignificant in most studies as above referred. 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 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. However, membership can also predict a range of social capital measures 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. 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.

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.

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