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ESSAYS ON SOIL CONSERVATION, SOCIAL CAPITAL AND TECHNOLOGY ADOPTION

Wilfred Nyanena

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ABSTRACT

Erosion of agricultural land remains a major constraint to agricultural development in Kenya, which has a complex topography. Government and donor institutions are promoting soil and water conservation practices. Several hypotheses have been put forward to explain the process and driving forces for the adoption of these practices. Yet there is a lack of accurate information on the determinants and benefits of these investments. A better understanding of the possible driving forces for adoption would help design research policy and mechanisms to facilitate beneficial outcomes from the process. A better understanding of the process is important because in Kenya, a growing population has pushed more people to farm on fragile and steeply sloped land. Furthermore, there are concerns that agricultural output and productivity growth lag behind population growth. One element that is hypothesized to have a bearing on soil conservation adoption is social capital, which is generally interpreted as the degree of trust, cooperative norms, and networks and associations within a society. Economic work on the role of social interactions for collective action, in particular for soil conservation, is still scarce. However, attention to the significance of social relations for economic outcomes and economic development in particular, suggests the pertinence of this study. The objective of this thesis is to provide a better understanding of the role of social capital and the economics of soil conservation by: (1) developing a method of aggregating social capital measures, (2) conducting a social economic analysis of determinants of soil conservation adoption in particular the impact of social capital differences, and (3) understanding the productivity impacts of different soil conservation structures. This thesis comprises three papers.

Paper1: This paper sets out to investigate two questions. First, it seeks to derive measures of social capital in agrarian societies using survey data. Second, the analysis verifies the hypothesis that there are differences in social capital between Machakos on one hand and Kiambu and Meru on the other. We find significant differences between Machakos and the other two regions.

Paper2: This paper examines two issues. First, we discuss how social capital may affect economic performance, in particular the need for collective action, as revealed in the theoretical and empirical literature. This has implications for whether social capital can be modelled as a determinant of farm technology adoption. Second, it examines whether and to what extent household and village level social capital affect plot level adoption of soil and water conservation.

Paper 3: Soil erosion is an important economic and environmental problem in Kenya. Physical soil conservation structures have been promoted as promising techniques for reducing soil erosion. Evidence regarding yield enhancing properties of these techniques is inconclusive. This paper provides an economic analysis of soil conservation investments and their impact on value of yield. Results indicate that soil conservation structures increase returns on degraded land and even increase the returns from some inputs.

JEL Classification: Z13, O13, Q10

Key words: Kenya, social capital, soil and water conservation, technology adoption, farm productivity

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CONTENTS

ABSTRACT i
Acknowledgements ii

CHAPTER 1. Soil Conservation, Social Capital and Technology Adoption 1:1
1. Introduction 1:1
2. Research gaps and implications for this study....... 1:6
3. Thesis plan....... 1:8
References 1:9

CHAPTER 2. Social Capital and Institutions in Rural Kenya: Is Machakos unique? 2:1
1. Introduction 2:2
2. Social capital, collective action and rural development 2:5
3. Data....... 2:9
4. Basic analytics of principal components 2:12
5. Results 2:14
6. Interpretation and discussion of the district differences....... 2:17
7. Conclusions 2:23
References 2:25
Appendix 2:28

CHAPTER 3. Social Determinants of Soil and Water Conservation in Rural Kenya 3:1
1. Introduction 3:2
2. Data....... 3:8
3. Modelling and estimation issues 3:15
4. Results 3:17
5. Discussion and conclusion 3:23
References 3:25

CHAPTER 4. Economic Assessment of Soil and Water Conservation Investments: An application to crop yield in Kenya 4:1
1. Introduction 4:2
2. Conceptual framework and hypotheses....... 4:6
3. Estimation....... 4:10
4. Results 4:16
5. Summary, conclusions and implications. 4:28
References 4:31

CHAPTER 1

Soil Conservation, Social Capital and Technology Adoption

1. Introduction

Land degradation in Kenya, manifested as soil erosion and soil nutrient loss, is widely seen as the major constraint to agricultural growth and poverty alleviation. Soil loss reduces both current and future productivity of land resources and contributes to water pollution. Since the 1930s there have been large efforts by the Kenyan government and donors to promote soil conservation and environmental rehabilitation. Currently, land degradation is an important issue in Kenya's Poverty Reduction Strategy Programme (PRSP), which links up to the policy of the country's overall development plan.

Many believe that land degradation has significant socioeconomic and environmental consequences for society. Farm technology adoption in farmer's livelihood systems can become an important element of survival. High population pressure and land degradation necessitate the adoption of farm technology for multiple reasons. First, technology adoption is an important element to mitigate the negative effects of soil erosion and nutrient depletion. Second, technology adoption can increase agricultural production which has consumption benefits to the poorer strata. Finally, any surplus production can be sold in rural and urban markets commercially. A broad range of literature on the adoption of farm technology in developing countries exists (see Feder, Just and Zilberman, 1985 for a review). It is often found that the probability of adoption is influenced by household characteristics, such as human capital, degree of risk aversion, farm size and biophysical characteristics. Consequently, various measures including economic incentives and coercion have been used to encourage adoption of soil and water conservation practices (SWC). Despite these efforts, the problem of land degradation continues and may be worsening in some regions, particularly in many of Kenya's fragile and steeply sloped areas. Policy makers are therefore looking for alternative strategies for these areas.

The objective of this thesis is to highlight the success of the Machakos District in SWC adoption, whose extent is considerably larger than what would be warranted by its socioeconomic circumstances. For this reason the 'Machakos miracle' has generated a great amount of interest in studying the theoretical and empirical factors underlying its success. While an increasing population undoubtedly exerts greater pressures on productive land and other resources, it is not necessarily population *per se* that causes land degradation. Indeed, research in Machakos shows that in the face of an increasing population pressure, farmers have managed semi-arid, once degraded and unproductive fields in a manner that has rehabilitated and made them profitable (Tiffen *et al*., 1994, Pagiola, 1994).

In this thesis, we explore the assertion that the organisation of a society affects economic performance. In particular, we examine the arguments for why social characteristics might affect preferences and constraints, and how they interact with economic factors to influence agricultural technology adoption and the impact of farm technology adoption on land productivity in Kenya. For instance, in addition to household characteristics, household behaviour can be influenced by behaviours of other households. At the same time, memberships in groups also mean members have more trust for each other, can rely on enforcement mechanisms to share risk and coordinate collective action efficiently, which in turn may be critical for the adoption of soil and water conservation measures. We attempt to examine whether there are variations in such social capital between Machakos on one hand and Kiambu and Meru on the other. In the literature, various attempts have been made to understand the impact of differences in such capital on a range of outcomes: economic growth (Knack and Keefer, 1997; Temple 1998), household incomes in Tanzania (Narayan and Prittchett, 1999) and the adoption of modern agricultural inputs in Tanzania (Isham, 2002). Other studies have tried to capture the impact of social interactions in technology adoption (Foster and Rosenzweig, 1995; Udry and Conley, 2001).

The overall goal is to improve our understanding of the economics of soil conservation in Kenya and elsewhere. In particular we identify alternative, effective and realistic paths out of the downward spiral of land degradation and attendant poverty in Kenya.

We do this by analyzing and quantifying some of the major factors that may have contributed to some areas successfully adopting and some not adopting conservation and productivity enhancing technologies.

The neo-Malthusian position is well-known. Poor people are often assumed to be caught in a vicious cycle in their management of natural resources. Due to a lack of resources and their struggle to ensure daily survival, poor farmers are believed to offset concerns with long-term sustainability of their resource management and instead degrade already fragile, steeply sloping, erosion prone hillsides (see Cleaver and Schreiber, 1994). Proof of this argument was evident in Machakos and other parts of the country. This Malthusian view was an accepted *fait accompli* with public discussions of population and development realms. However, the experience of Machakos as reported by Tiffen *et al*., (1994) has opened up new thinking on soil degradation. It challenges the neo-Malthusian view of population growth as the primary generator of environmental degradation and poverty. The authors show pictures taken in the 1930s of seriously eroded landscape which to some extent cast doubt on the ability of the regions to support both the human and livestock population. The situation persisted into the 1960s when projections for the region mirrored a Malthusian type of poverty trap with widespread deforestation and chronic fuelwood shortages. However, none of these environmental and economic catastrophic predictions have taken place. Few can dispute that although the population has increased fivefold, there has been a threefold increase in the value of agricultural output per head in real terms.

The notable change in Machakos presents an interesting development in the agrarian economy of Kenya. The hallmark of land improvement investment in Machakos has been the construction of physical soil and water conservation measures. Replicating the Machakos success requires a better understanding of why some regions succeed while others do not. In particular the environmental recovery paradigm[1] has created a subject for analysis and debate (English *et al*., 1994; Barbier, 2000; Zaal and Oosterndorp, 2002). Many have observed that there was no special or unique approach developed for Machakos (Barbier, 2000). Consequently, there is no reason why similar results cannot

[1] A paradigm is a description of a subject that includes definitions, identification and descriptions of variables, and expected cause and effect relationships.

be replicated across many other regions in the country where many rural smallholders are struggling with problems of land degradation and low agricultural development. Policy makers are very often concerned with the persistence of disparities among regions in terms of economic and social performance. Thus it is of interest to replicate the Machakos experience in other regions of the country and elsewhere. Moreover, approaches that promote agricultural development have much wider impacts like reduction of hunger, increased incomes and other measures of welfare.

Following the seminal work of Putnam (1993), social capital has been shown to have important economic effects at the micro and macro levels. Social capital is generally interpreted as the degree of trust, co-operative norms, and networks and associations within a society. Various arguments have been advanced as to why higher levels of social capital can lead to improved economic performance. These include the reduction of monitoring and enforcement costs, improving information flows, fostering of exchanges for mutual benefit by developing reputation dissemination and promotion of consultative decision making and collective action that minimizes negative externalities and promotes the production of public goods. Additionally, there is coordination and facilitation in economic transactions when markets are missing or incomplete (Narayan and Prittchett, 1999). Social capital is also believed to be a major asset because it lowers enforcement costs, favours exchange of knowledge and provides insurance. However, it has to be acknowledged that there are also cases where social capital can have negative effects. It is possible that some customs or norms may hinder the introduction of new techniques.[2] It is quite possible that farmers may be reluctant to introduce new techniques to improve productivity, because they go against the usual way of farming.

Social capital is not only found in locally embedded communities that share values and norms, it is also developed at the village level where higher-level interactions may take place. However, despite these theoretical claims, social capital has remained a problematic notion both on the conceptual and empirical levels. In poor rural agrarian communities with constraints on local asset stock and access to external resources,

[2] For example Rogers (1983) discusses the example of a Peruvian village whose members largely refuse to boil their drinking water because according to local custom only the sick are permitted to drink boiled water.

farmers lack credit, information and technology. If social capital has indeed such positive economic effects, it becomes important to understand its components. Given the difficulty of measuring such an 'intangible' asset as social capital, this thesis attempts to derive such a measure. Our social capital variables include economic groups such as cooperative societies and credit groups and not only socio-political groups as in Putnam (1993). Understanding these links in a developing country is crucial because such groupings and networks serve the functions that in developed nations are served by formal institutions and the market. Such a clarification will shed more light on the functioning of informal institutions and how economic policy could influence them.

Several aspects of the Machakos experience have confounded and attracted the attention of researchers. Behavioural change involves more than technical and financial considerations. The social process around adoption of technology at the plot level is complex and not well understood. The social, economic, physical and technological contexts of other farmers are possibly more relevant than understanding the individual plot owner. There is evidence that farmers who are active in 'networks' are more likely to put changes into practice. After examining studies on agricultural and non-agricultural settings in developed and developing countries, Rogers (1995) concluded that early adopters have greater social participation. Detailed understanding of the determinants of such phenomenal change is sought. Both economic and physical factors have been tested to explain their role in spurring the transformation. In this thesis we contribute to the literature by drawing out some important but less well-recognized social and economic relationships that may augur well for soil conservation. In drawing a few bold lines through the tremendously complicated subject of 'social capital' we add some more insights to the discussion on sustainable land management. The concept of social capital and its relevance to the issue of soil conservation is explored using data from Kenya. In addition, a broader and equally important purpose is to introduce a tool and process for amending and reviewing further hypotheses for collective action.

An understanding of the links between maintenance of natural capital and continued productivity of that capital come together into a local concern over the status of natural capital. The understanding that maintenance of natural capital is important to maintain agricultural output leads people to reinvest in natural capital and technology to increase productivity.

Naturally, economists are interested in understanding the circumstances under which a one time investment in technology and natural capital from outside sources pushes income up sufficiently to produce a surplus that is then reinvested. In this manner, the Machakos district, over a period of several decades, moved from the downward spiral of natural capital mining and declining real income into the upward spiral of investment and rising real incomes. The shift from a downward to an upward spiral reflects both improved techniques and direct investment in natural capital - the return to measures to maintain soil productivity or reversal of depletion. When explaining the increased prosperity of the area, Tiffen *et al*., (1994) argue that agricultural growth has accompanied a stabilization of the natural resource base.[3] The challenge is to understand the mechanisms that have enabled this transformation.

2. Research gaps and implications for this study

Given the success of Machakos, it is pretty surprising to observe that there are few analyses attempting to systematically evaluate the existing knowledge gained from the experience. Rather than validating the findings in Machakos, which is what most studies have focused on, steps should be taken to thoroughly analyse what is really unique about Machakos by comparing it with neighbouring districts in near similar circumstances. What would farmers in these regions need in addition to their existing assets to adopt soil conservation and increase their household welfare?

Thus far the debate over intensification has hinged on private incentives to halt land degradation. Absent from the debate is the role of social capital in coordinating soil conservation efforts between neighbouring plots, creating incentives, removing barriers for collective action and as a source of information for soil conservation. The potential of social capital to internalise economic externalities and provide other resources is of particular interest in natural resource management. Existing studies only focus on

[3] There is always a possibility, however, that slow but subtle depreciation of natural capital is still working against long-term sustainability of agricultural production.

certain economic characteristics of the production system ignoring the importance of social factors that may be critical contributors to adoption decisions. For instance social capital in the form of concern for other members of the community has the potential to motivate individuals to act for the collective good. Where community groups exist, social capital may further help individuals overcome resource barriers to soil conservation, by providing collective labour and capital. Additionally, information and knowledge on farming may flow easily and extensively due to the many social ties among most farmers among each other.[4] Unlike many past studies that only analysed economic factors affecting adoption, this thesis analyses both the social and economic determinants of soil conservation investments. The objective of this thesis is to examine whether social capital coupled with economic factors hold promise for inducing sustainable land management under conditions where population growth alone is unlikely to ignite intensification. The impact of socio-economic factors is based on looking at variables like social organisation and structure of a locality.

Also unlike many past studies that only analysed factors affecting adoption of SWC technologies, this thesis analyses the productivity of different soil conservation measures. This analysis will be used to design strategies for increasing productivity and hence adoptability and sustainability of the practices. The impact of SWC on productivity can be expected through the effects on other inputs and their interactions. Few studies document the impacts of SWC technologies on agricultural productivity. Existing information about the impact of the technologies on agricultural productivity (i.e. the input-output relationship after adoption) is only sparsely available. In Chapter 4 we evaluate the impact of adopting soil conservation measures on crop yield. A production function that relates agricultural input and soil conservation measures to yield is utilised to examine the contribution of soil conservation on agricultural productivity. The production function accounts for the fact that expected yield depends on inputs used in production and on current or past decisions to adopt soil conservation measures.

[4] Similarly, customs or norms can also hinder communication between economic actors (see Knorringa, 1996).

3. Thesis plan

The overall objective of the thesis chapters is to identify effective and realistic strategies out of the downward spiral of land degradation in Kenya. This means to understand and to quantify the factors that influence adoption or non-adoption of soil conservation technologies. Additionally, it is of paramount importance to show if these technologies enhance land productivity and identify the results of such an adoption.

The plan of the thesis is as follows. In Chapter 2, we discuss the conceptualisation and measurement of social capital variables in a rural agrarian setting. We address such questions as: What are the different dimensions of social capital in rural areas? Are there differences in social capital levels between the regions? Why is it that different communities have different levels of social capital? We make comparisons between districts to clarify whether or not there is more social capital in Machakos. These are relevant questions because they broaden our understanding of a vague concept. Chapter 3 investigates the determinants of soil conservation investments, and in particular the association of social capital variables at individual and community levels with SWC adoption decisions. The question of whether social capital measures have impacts on economic outcomes has been at the core of recent debates, so Chapter 3 is devoted to examining this hypothesis. We link measures of individual and communal social capital with other important economic variables and examine their effect on adoption of soil and water conservation practices. The existing evidence of the impact of soil conservation on crop productivity is not clear-cut. There is work that suggests that soil conservation increases agricultural productivity. On the other hand there is also research that has failed to find strong evidence for the investment and productivity effects. Thus, in Chapter 4 we evaluate the productivity on plots with and without soil conservation as well as the interaction between SWC and plot characteristics as well as agricultural inputs.

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CHAPTER 2

Social Capital and Institutions in Rural Kenya: Is Machakos unique?

Wilfred Nyangena†
Department of Economics,
Göteborg University,
SE 405 30 Göteborg, Sweden
Wilfred.Nyangena@economics.gu.se
Fax +46 31 7731326

Abstract

In Eastern Africa, the experience of Machakos has been heavily debated between Malthusians and the more optimistic Boserupians. Machakos was the epitome of overpopulation and resource degradation in the 1950s but has since thrived. The Boserupians see Machakos as an illustration of how population growth can solve rather than exacerbate the vicious cycle of poverty and resource degradation. However, Machakos appears fairly unique. The purpose of this study is to see what role social capital may have played in Machakos. Using principal components we estimate various dimensions of social capital and find significant differences between Machakos and two other Kenyan regions.

Key words: **Kenya, Social capital, soil conservation, principal components**

JEL classification: A12, D23, Q16 Z13.

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1. Introduction

Capital is clearly vital for economic development, but the first growth accounting studies such as Solow (1956) focused on physical capital and found that it could not fully explain economic growth. Later attention has focused on other forms of capital, including human capital in the form of skills, training and education (Becker, 1964), and organizational capital (Prescott and Visscher, 1980). Similarly, it has been pointed out that social structure is an important determinant of economic activity. Features of social structure and organisation such as trust, norms that facilitate coordination and cooperation are increasingly called 'social capital,' (Coleman 1988, 1990; Putnam, 1993). Intuitively, the basic idea is that social capital constitutes an important asset, one that can be called upon in times of crisis, enjoyed for its own sake, used for material gain (Woolcock and Narayan, 2000) or to resolve disputes (Schafft and Brown, 2000). Some claim social capital is an important new category in the analysis of economic growth.

Pessimism currently pervades much of the debate on the ability of Africa to feed her population (World Bank, 2001). The vicious cycle of land degradation and increasing poverty has been described as a downhill spiral leading to a poverty trap (Cleaver and Schreiber, 1994). Population pressure leads to cultivation of new lands that are frequently inferior due, for instance, to steep slopes and high soil erosivity. Soil erosion leads to poverty, short-sightedness and insecurity and possibly to large families, population explosion and land fragmentation.

This bleak Malthusian picture has however been strongly criticized by a high profile series of very optimistic studies of the Kenyan Machakos district. This region had all the characteristics mentioned above already in the 1950s: it was considered to be overpopulated, eroded and poor. The prospects were that it would deteriorate further through population growth, smaller holdings, more erosion and declining income. Instead there has been remarkably successful land management and impressive success in food production not only for sub-national and national markets but also for export (Boserup, 1965; Tiffen *et al.,* 1994). According to Boserup and Tiffen, Machakos was not overpopulated and overgrazed, but underpopulated. The solution was more population, better technology and management. This so-called 'Boserupian hypothesis' is of considerable importance for the development literature and in particular for the prospects of sustainable development. In the literature, there are many variants of the Boserup hypothesis. The insight given in those studies is that an increasing population motivates even poor farmers to invest in soil conservation. From this perspective, declining land productivity is endogenously self-correcting, which does not imply that population pressure will always lead to more intensification and hence should be counted as something positive. The issue at stake is whether we are correct in worrying about overgrazing, erosion, forest degradation and other phenomena related to a growing population density, or whether the problems are mainly transitional and perhaps an increasing population density is in fact a step towards solving rather than causing or aggravating resource and poverty issues.

Case studies designed to test the 'Boserupian hypothesis' yield contradictory results. Ovuka (2000) studied, similar to Tiffen *et al.*, (1994), Murang'a (which borders Kiambu) between 1960 and 1996 and found an increased population, declining conserved land and soil fertility. Consequently, she concluded that more people led to more erosion. Besides population pressure, Zaal and Oosterndorp (2002) found that market access factors (distance to markets, prices etc), external influence and enabling government policies were significant in determining agricultural intensification. Similarly, it has been suggested that Machakos' success is due to the proximity to the capital Nairobi, which provides a ready market for agricultural produce.

Naturally there are other studies not supporting the Boserupian hypothesis and there are many cases providing evidence of escalating population density and resource degradation (Pender *et al.*, 2004). Resolving these divergent outcomes is very important for policy makers given the crucial role that agriculture plays in any initiative of poverty reduction and rural development. Mazzucato and Niemeijer (2002) provide an interesting study showing that it is not just the population density *per se* that decides whether resources will be developed or degraded. Instead they argue that how people adjust to the rise in numbers is decisive, and focus on the role of local informal institutions, such as land tenure systems, but also on customs, norms, and networks which are among the prime determinants of what we refer to as social capital. This study aims at identifying if there are differences in social capital between the Machakos district and the two other districts Kiambu and Meru, and if any differences found can cast light on the apparent differences in their ability to build a sustainable and thriving agriculture. The three districts are, at least superficially, very similar when it comes to household and agro-ecological characteristics. Also all three have high and growing population densities (see Table 1). Machakos has been through its resource crisis and is thriving (at least in relative terms). The number of poor people is also the lowest as shown by the district's contribution to the country's overall poverty. This proportion takes into account (i) adult illiteracy rate and (ii) a composite index of deprivation in economic provisioning.[1] In terms of agricultural earnings per hectare in Kenya Shillings, Kiambu is closer to Machakos, than Meru although no adjustments are made for proximity to markets.

Our interest in this study is directed to those features of culture or institutions that are commonly referred to as social capital, and that are particularly relevant for the collaborative action when it comes to the improvement of agriculture. Agriculture in these regions faces a number of barriers in addition to soil erosion, the difficulty in acquiring adequate inputs, distance to markets, lack of insurance, credit and market information as well as high transaction costs in general.

Table 1: Agro- ecological, climate and socio-economic characteristics

	Kiambu		Machakos		Meru	
Mean annual rainfall (mm) [a]	1250		1190		1300	
Agro Ecological Zone [b]	UM3-4		UM3-4		UM2-3	
Nr of households	189,706		186,297		120,265	
Contribution to poverty	1.48%		1.32%		2.4%	
Population density	**1989**	**1999**	**1989**	**1999**	**1989**	**1999**
(Persons/Km^2) [c]	588	660	462	539	579	769
Nr of women groups	1147	4036	2073	5936	954	5026
Earnings per Hectare		1179		1242		870

Source: Relevant District Development Plans. a Recorded in the nearest Met station. b Agro-climatic zoning developed by Jaetzold and Schmidt (1983). c Refers to study area population density, and due to administrative boundary changes in the 1990s previous population density values are not comparable.

[1] This is indicated by the population without access to safe water, population without access to health services and underweight children under age five.

A number of these difficulties can at least partly be overcome by collective action. It is these social capital features of institutions and culture that facilitate such action that are at the core of our interest.

A peculiarity of social capital is that it cannot be directly measured and at best, we are faced with indicators reflecting specific features of social structure. Empirical handling of many such measures is difficult. We try therefore in this paper to use Principal Component Analysis (PCA) to find some relevant and intuitively appealing variables that will conveniently summarise relevant aspects of social capital that may help explain differences in economic development. We believe it should be of considerable policy interest to identify and promote factors facilitating cooperative capacity for addressing rural development.

The paper is organised as follows. In Section 2, we discuss the theoretical links motivating the development of social capital constructs in the context of soil conservation. We present the data and discuss the measurement approach in Sections 3 and 4, respectively. Section 5 presents an interpretation of the principal component results. A discussion of the district differences and possible explanations are provided in Section 6. Concluding comments and policy implications are given in Section 7.

2. Social capital, collective action and rural development

Social capital is an elusive concept. On the one hand, the central ideas were formulated a long time ago. One example is the paper by de Tocqueville (1840) in which even the title is still a pertinent formulation of current research issues with its focus on ‘the use that citizens make of public associations’. This paper highlights the importance of associations primarily for purposes of overcoming the restrictions in the credit and labour markets that would otherwise make large undertakings difficult. By highlighting this, the author ties social capital to democracy and market economics. He follows up by citing examples where associations build trust, confidence, moral values and have value in providing information; he ties the importance of associations to the freedom of press, cooperative or collaborative efforts and democracy. Although written in the USA almost two centuries ago, many of his concerns are important issues in Kenya today.

One prominent book with quantitative measures of social capital is Putnam (1993) on the differences in social capital between North and South Italy. He argued that different levels of social capital could best explain the differences in democracy and economic development between these regions. The study distinguishes two now widely used types of social capital: bonding capital located in groups, and bridging capital found in the connections between people across groups. Hence associational life, or voluntary group membership, is an important variable in many social capital studies including ours. Fukuyama (1995) also emphasizes association membership but then argues that it is shared norms and values that underpin behaviour and motivation.

A careful attempt to define social capital is given by Collier (2002) who argues that the social component requires measures of social capital that are borne out of social interactions and are capable of producing external effects such as: increasing the stock of knowledge, reducing the scope for opportunistic behaviour or preventing the free rider problem of collective action. The capital element requires that measures have longevity that are independent of the social interactions that generated it.

There is however an important critique of the concept of social capital stemming from its limited theoretical underpinnings and lack of empirical scrutiny. While acknowledging in general terms the beneficial effects of social capital, Dasgupta (2003) is fairly negative to the term itself. He argues that some elements of social capital are private and hence already included in human capital (see also Glaeser, Laibson and Sacredote, 2002; Sobel, 2002). Dasgupta recognizes that there are many important institutions, networks and other aspects that are 'social' and not individual, such as all the phenomena that comprise the market institutions, public good resources and resource allocation mechanisms of society. Dasgupta argues that it is not possible to carve out a particular subset that can meaningfully be called social capital.

There is no doubt much to be said for this position. We are in this paper interested in analysing certain socio-cultural and organisational traits of society such as the tendency to form associations and to invest in trust in order to facilitate cooperative efforts, communal action and overcome barriers such as transaction costs, lack of information or insurance. These traits are commonly referred to as ‘social capital’ and we retain the term for convenience as a label for a number of interesting variables, without necessarily taking any position as to whether this term rightly should be given a similar dignity as for instance the term ‘human’ capital.

Inextricably linked to the definition of social capital is its empirical measurement. For those who view social capital as the property of the group rather than the individual, the most common measures examine membership of voluntary organisations, churches or political parties. An important element addressed here is not mere membership but also the intensity of engagement. Social trust has been used in many studies as a means of approximating levels of social capital. One contentious issue with this measure, however, is how to define trust. There is a danger in using single questions about trust and linking them to broad measures of a nation’s economic performance (Baron *et al.*, 2000).

In a pioneering study of social capital in developing countries, Narayan and Pritchett (1999) examined the links between social capital and village level economic outcomes in Tanzania (of particular relevance here with its many ecological and cultural similarities with neighbouring Kenya). They asked questions about household membership in groups, the characteristics of the groups and individual values and attitudes. A novel feature in this study is the use of the oft quoted social capital operational features trust and membership in associations. The study confirms the importance of heterogeneity in group membership for economic outcomes. The authors concluded that performance was influenced by the communities’ past experiences in how to organise cooperatively.

In an analysis of household welfare in Indonesia, Grootaert (1999) treats social capital as a production factor like physical or financial capital. He investigated the link between social capital, household welfare and poverty using a multivariate analysis. The study identified six dimensions: density of associations, internal heterogeneity, frequency of meeting attendance, decision-making, payment of dues and communal orientation of the associations from which a social capital index was constructed. This turned out to be positively related to household welfare which is interesting (even though an additive index with equal weights was used, which is clearly questionable). Similar positive relationships between income and group membership are reported in La Ferrara (2002) for women in the slums of Nairobi, and in Haddad and Maluccio (2003) who focused on rural South Africa.

In a study of watershed management in 60 villages in India, Krishna (2001) investigated the link between social capital and development performance. This study defined social capital dimensions corresponding with an agrarian society in circumstances relevant to Kenya. The key finding was that high stocks of social capital were a necessary but not sufficient condition for community development. He concluded that social capital needed to be complemented with information and connections with markets and the state in order to be effective. Broadly speaking the operational features describing social capital are ‘membership in voluntary organizations’, ‘trust’ and ‘community affiliation’.

There are a number of other studies in developing countries showing that a defining feature of being poor is exclusion from social networks and institutions. Without access to networks, credit, information, insurance etc it is hard to work one’s way out of poverty (Fafchamps and Minten, 2001; Fafchamps and Lund, 2003; Fafchamps, 2004). These analyses contribute to the understanding of how social networks play a role in economic outcomes through risk pooling. The current study seeks to provide a richer understanding of how soil conservation decisions are embedded in a social context. There are several direct or indirect channels through which social capital may affect soil conservation. First, a farmer may learn about a technology via other farmers. A positive or negative attitude of the farmer’s group towards the technology may influence his behaviour. Thus a social group can affect demand for SWC adoption directly. Second, social capital may also affect SWC adoption via features of social structure that ease economic constraints (for instance labour pooling and sharing farm implements for terrace construction). Finally, communities with high degrees of social capital may find it easier to solve collective action problems than societies less well-endowed with social capital. For example, there is a need for coordination in the construction of SWC structures between neighbouring farms. It is thus of particular interest to ascertain whether there are measurable differences in these mechanisms between the successful Machakos and the other communities of Kiambu and Meru.

3. Data

The study draws on survey data collected from 356 rural households in Kenya during the January–April 2003 period. The survey randomly took samples from each district. From the sub-locations, we selected 10 villages randomly and 20 households from each of the chosen 10 villages[2]. A household level questionnaire collected information about relationships, membership in voluntary groups and associations, monetary and in-kind contributions, sources of agricultural and sources of private and public information. The survey information was complemented by focus group discussions. The social networks literature suggests that resources are found in personal relationships that the household maintains. The interpretation, meaning and cultural context of 'norms' and 'values' vary within and across countries. Hence any attempt to measure social capital needs recognition of the limitations as well as the analytical potential of universal and un-differentiated categories such as general trust, association membership, reciprocity and engagement with respect to underlying notions. Also necessary is the precise measurement construct used to capture the concept.

The questions were based on World Bank studies of social capital, poverty and development (see www.worldbank.org/poverty/scapital/index.htm). The questions were first refined based on information from key informants among village leaders. It was then further developed in a series of focus group discussions. In particular, we found that it was important to clarify the questions concerning trust to make the issues clear to farmers in these closely-knit societies.

Despite some ambiguity, social capital is generally understood as a property of the group rather than the individual. Hence, the most common measures put emphasis on membership in associations. Accordingly, our first set of questions (C1-C5) relates to participation in groups and voluntary organizations as formal sources of social interaction (Putnam, 1993; Paxton, 1999; Li *et al.*, 2002). The second group of

[2] A multi-stage sampling procedure was used to select the sample with the random population of households to yield 12 households per village.

questions (T1-T5) intends to capture household contacts and intimate interactions with personal friends, but not (necessarily) in formal associations. The third group focuses on neighbourhood interactions and the fourth on information flows. Summary statistics of the data are provided in Table 2.

Table 2: Descriptive statistics of social capital indicators

Variable	Ref[a]	Kiambu	Machakos	Meru
Membership in any association [b]	C1	0.91	0.96	0.90
Number of associations to which individual belongs (0 to 3)	C2	1.30	2.00	1.47
Number of meetings per month (0 to 34)	C3	2.83	6.02	3.05
Monetary contributions per annum (‘000 K Shillings) (0 to 96)	C4	3.8	3.6	5.1
Value of monetary benefits per annum (‘000 K Shillings)(0 to 68)	C5	3	2,9	4
Number of close friends to discuss personal matters (0 to 45)	T1	3.9	4.5	3.8
Number of persons who can lend you money during crisis[c] (1 to 4)	T2	2.7	2.6	2.7
Number of persons who can give you food during crop loss[c] (1 to 5)	T3	2.4	2.5	2.4
Number of people who sought household’s assistance (0 to 24)	T4	2.6	3.1	2.5
Value of assistance given out last year (‘000 K Shillings) (0 to 30)	T5	2.1	1.2	1.3
Lent out significant amount of tools[b]	NI	0.85	0.83	0.95
Received significant amount of tools[b]	N2	0.84	0.77	0.94
Will contribute time to project without direct benefits[b]	N3	0.03	0.07	0.03
Will contribute money to project without direct benefits[b]	N4	0.00	0.08	0.02
Participated in any community project last year[b]	N5	0.48	0.63	0.75
Media is important source of market information[b, d]	I1	0.47	0.20	0.23
Relatives important source of market information[b, d]	I2	0.63	0.35	0.31
Neighbors most important source of market information[b, d]	I3	0.56	0.52	0.53
Relative most important source of government information[b, d]	I4	0.35	0.39	0.33
Media most important source of government information[b, d]	I5	0.47	0.38	0.43
Public agents most important source of government information[b, d]	I6	0.52	0.49	0.52

[a] This column provides a key to the variables for convenience. The full survey is available on request.
[b] YES=1, NO=0. [c] Excludes family members. [d] Variables I 1-6 measure whether or not the relevant source is mentioned among the three most important (out of 12 possible) sources.

The extent of association involvement starts with a simple yes/no question followed by the number of groups people belong to (C2), number of group meetings (C3) and finally material contributions to voluntary associations and benefits received from them (C4-5). Note that these features are closely linked to membership in groups and active participation in them (Fukuyama, 1995; Warde *et al*., 2003). The obtained level of civic participation should be a reasonable measure of the household’s social capital resulting from formal involvement in voluntary groups.

The first three questions relate more to how much people put into associations, and Machakos has higher values. The two questions C4-5 are somewhat different: the amount of money people contribute or receive partly reflects the strength of the associations but also is a reflection of the financial needs of group members during the year. Machakos does not come out higher on these variables – maybe because its people did not need to borrow much money during the year. This could in principle be a sign that Machakos is wealthier and thus the interpretation of questions C4-5 is somewhat more complex.

Naturally, the family itself is an important asset (for general welfare as well as for production) but this is (at least partially) captured in variables describing family structure. The second group of questions attempts to measure the dimension of social capital assessing whether the individual has friends to rely on for emotional and practical support. We aim here at capturing friendships that are 'strong ties' or bonding links as distinct from 'weak ties' (Granovetter, 1973). The third group of questions is intended to capture these weaker ties also commonly known as 'bridging' or community engagement social capital. These indicators are not necessarily mutually exclusive. They measure community engagement and volunteering effort, meaning how closely people associate with their neighbourhood and their willingness to participate in projects from which they derive no immediate personal gains. Community engagement reveals a shared sense of capacity to affect change at the community level while volunteering is understood as commitment of unpaid time or money outside the household for the benefit of others. This distinction is important in isolating situational networks arising when people form networks around settings over which they have no control, for instance amongst neighbours.

Another important dimension of social capital concerns the exchange of information among stakeholders. Information is vital for production and other management decisions on the farm and has considerable market value. Some network members have the ability to obtain information both from their own sources and from contacts with others through informal chats on issues of common interest. Some members have access to expensive commercial or official media channels like television, radio and daily newspapers that relay important information that is beyond the reach of many poor neighbours or friends. The return to an individual providing information to others is power, reputation and satisfaction (Lin, 2001).

4. Basic analytics of principal components

Aggregating and interpreting this wealth of information is hard. Casual inspection of Table 2 shows that Machakos does score somewhat higher on many – but far from all – of the questions. People spend more time with associations, but receive less assistance from them. They have more friends, which is not necessarily reflected in the number of friends they would turn to for economic assistance. The information is multidimensional and many of the answers are interlinked.

In the literature, aggregation methods vary from ad hoc weighting and addition of indicators scores to the calculation of weights for each indicator. For example an expert panel of policy makers or rural farmers could determine the weights. These relatively simple methods are plagued by conceptual and methodological problems. Firstly, they are based on the assumption that all selected indicators measure the same underlying concept. Additionally, it is assumed that the selected indicators are perfect measures ignoring possible measurement errors.

We use principal components analysis (PCA) to overcome these problems. The PCA is a popular and standard technique used in the literature for inequality dimensions (Maasoumi, 1986), poverty and welfare (Sahn and Stifel, 2000) and in social capital analysis (see Grootaert, 1999; Narayan and Pritchett, 1999). It is used in this paper for two closely related purposes. First, to identify latent, non-observable structures, using associations between indicators. The underlying assumption here is that there are a number of unobserved (latent) variables of interest, in our case various aspects of social capital such as trust and social cohesion. We assume that the measures created by answers to our questions at least partially reflect these underlying variables. The second goal is to reduce the dimensionality of the original data set. A smaller set of uncorrelated variables is easier to understand and use in further analyses than a larger set of correlated variables. The main idea is to find appropriate and practical ways to utilize the available data in lieu of the data that would have been theoretically desirable. Principal components analysis seeks a few uncorrelated linear combinations of the original variables that capture most of their information. For example, a set of T 'time indicators' such as number of monthly meetings, duration of church meetings, time spent at the café with friends etc., can be characterised as a vector $(t_1, t_2 ......t_p)$ and linearly transformed by $F = a_1t_1 + a_2t_2 + ... + a_pt_p$ into a one dimensional 'FRIENDS' index F. The weights are mathematically determined to maximize the variation of the linear composite with the original variables. The linear composites[3] are ordered with respect to their variation so that the first few principal components together account for most of the variation present in the original variables.

Algebraically, the first principal component, F, is a linear combination of $t_1, t_2 ......t_p$, $F = \sum_{i=1}^{p} a_{1i}t_i$, such that the variance of F_1 is maximized given the constraint that the sum of the squared weights is equal to one, i.e. $\sum_{i=1}^{p} a^2_{1i} = 1$. The random variables, t_i, can be either deviation from mean or standardized scores. Principal components analysis finds the optimal weight vector $(a_{11}, a_{12} ......a_{1p})$ and the associated variance of F_1 that is denoted λ. The second principal component F_2 is similarly defined, but the optimisation is subject to the constraint that the vector be orthogonal to or independent of F so that $\sum_{i=1}^{p} a_{1i}a_{2i} = 0$ and $\sum_{i=1}^{p} a^2_{2i} = 1$. The procedure continues with more components and as successive components are extracted, the variance of the principal components gets smaller. The first few components have the highest possible sum of squared correlation with the original variables. This process is continued until as many components as variables have been computed. However, the first few principal components usually account for most of the variation in the variables and consequently

[3] The composite can be based on either a covariance or a correlation matrix. The latter is a covariance matrix of standardised variables, and is used in this analysis since it avoids problems caused by different scales for the variables. (See Duteman, 1994; Johnson and Wichern, 2002 for elaboration).

our interest is focused on these. The main statistics from a principal components analysis are the loadings or weight vectors **a**= $(a_1, a_2, ...a_p)$ associated with each principal component and its associated eigenvalue or variance, λ. The pattern of eigenvectors for a principal component is used to interpret the principal component, and the magnitude of the eigenvalues provides an indication of how well they account for the variability in the data. The relative sizes of the eigenvalues indicate the relative contribution of the variable to the variance of the principal component. Such a specification permits the reproduction of a maximum amount of information contained in the original data (Maasoumi, 1986).

5. Results

Table 3 shows the eigenvalues for the first four principal components of all observations. The question of how many principal components to retain is not readily resolved. The issues to consider include total sample population explained, the relative size of the eigenvalues and the subject matter of interpretation of the components. A commonly used guide is the Kaiser criterion in which we retain only values with eigenvalues greater than 1. This means that, unless a factor extracts at least as much as the equivalent of one original variable, it is dropped.

Table 3: Results from the principal component analysis

	1st PC	**2nd PC**	**3rd PC**	**4th PC**
Eigenvalues	2.39	2.05	1.67	1.41
Variance	0.12	0.10	0.08	0.07
Cumulative	0.12	0.22	0.31	0.38
Sphericity test:	Chi square=1120.4degrees of freedom 190			

Using Cattell's scree[4] plot criterion shows a steep slope from the first to the fourth component. However, the 5th to the last can be fitted fairly well by a straight line of negligible slope. Furthermore, the fifth and sixth components were very hard to interpret. The first four had, as we will see below, clear loadings that could be

[4] This is a plot of the obtained eigenvalues versus components, and retaining factors, which are above the inflection point of the slope.

interpreted as groups of variables with a common interpretation. From the fifth eigenvector and on, the loadings were smaller and the variables hard to group intuitively. Consequently, we base our discussion on the first four components. This means that we have narrowed down our data set from 19 original variables to 4 new ones that still explain 38% of all the variation in the original variables.

The PCA is sensitive to the magnitude of correlations. Hence, robust comparisons of the indicators must be done to ensure quality of the eigenvalues and scores. A measure of such appropriateness of the overall model is given by Bartlett's sphericity test, which tests whether the correlation matrix is an identity matrix. This is thereby a test of how the whole approach works in this particular case since it tests the hypothesis that the eigenvalues and consequently the principal components are equal (null) versus the alternative of different eigenvalues. The hypothesis of equal eigenvalues is rejected at the 1% level of significance as evidenced by the large chi- squared value of 1,120 against 190 degrees of freedom.

Table 4: Loadings on the first four principal components

Variable	Ref	Factor 1	Factor 2	Factor 3	Factor 4
Membership (yes/no)	C1	0.363	-0.119	0.195	-0.061
Number of associations	C2	0.508	-0.163	0.161	-0.034
Number of meetings	C3	0.421	-0.159	0.053	-0.062
Monetary contribution to associations	C4	0.236	-0.037	0.081	0.169
Benefits received	C5	0.272	-0.159	-0.038	0.176
Number of close friends	T1	0.155	0.345	-0.196	0.115
Nr of persons to help in econ crisis	T2	0.221	0.513	-0.206	-0.079
Nr of persons to help with crop loss	T3	0.274	0.431	-0.245	-0.099
Value of assistance given last year	T5	0.015	0.088	0.001	-0.143
Lent tools to neighbours	N1	-0.049	0.347	0.565	-0.058
Borrowed tools from neighbours	N2	-0.076	0.302	0.588	-0.074
Prepared to contribute time	N3	-0.085	0.038	-0.251	0.103
Prepared to contribute money	N4	-0.029	-0.099	0.028	0.062
Participated in community project	N5	0.339	0.019	0.069	-0.029
Main source of market info: Media	I1	0.016	0.121	-0.107	0.124
Main source info: Relatives	I2	0.101	-0.069	0.046	0.505
Main source of info: Commune	I3	0.034	-0.211	-0.010	-0.475
Main source of govt. info: Relatives	I4	0.104	0.082	-0.104	0.035
Main source of govt. info: Media	I5	-0.019	-0.087	0.155	0.447
Main source of govt. info: Public	I6	0.033	-0.172	-0.043	0.399

Table 4 presents the results for the four eigenvectors retained. There is a high degree of correspondence between the variables that actually compose the various principle components and the groups into which the variables had originally been placed in the questionnaire.

Thus, the first principal component has high positive loadings for three out of the five variables C1-C3, with which we intended to cover the role of associations (*Member, Associations, Meetings*) and one additional variable that comes from our third block of variables, N5, (*Participation in community projects).* We call this factor simply 'Associations.' It principally covers the tendency of people to join associations and spend resources, time and money on them. Note that also the variables C4-5 as well as T3 and T2 have fairly strong correlations with this latent variable. Although we have set the cut-off for inclusion to 0.3, these additional correlations do not contradict but reinforce this interpretation of the first latent variable as a measure of associations.

The second principal component, which we have called 'trust', consists of the variables T1-3 (*Number of friends in general and who you would turn to for help in crisis or in the event of a bad harvest).* We thus find three of the five selected variables we selected to represent friendship. These three are clearly interlinked in realistic everyday situations covering reciprocity and trust in Kenya.[5]

The third component focuses on the lending and borrowing of agricultural tools mainly between neighbouring farms, and consequently we call this latent variable *neighbourhood cohesion.* The negative loadings on some of the friendship variables really indicate that there is a distinct, professional neighbourhood collaboration that is at least to some extent separate from the more personal friendship ties captured in PC2.[6]

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[5] Although there is precedence in the literature (Zak and Knack, 2001) for using TRUST as a proxy for social capital, it is important to acknowledge that the definition of this variable can be problematic (see also Glaeser *et al.*, 2000).

[6] Note however that PC2 also has fairly strong loadings for N1-2, but since these two variables form the only two components of the third PC (with higher factor loadings) they were excluded.

Finally, it is fascinating to see how separate the fourth group of variables is. It concerns where and how an individual member of the community finds information concerning both markets and other more official matters, and receives low loadings in the first three principal components and in the fourth component. Practically all other variables on trust, friendship and associations also have low loadings. The strongest loadings for the fourth PC are found on variables I2-3 and 5-6. It is worth noticing that I3 is negative and is presumably a strong substitute for one of the other sources of information (maybe I2). It makes sense to call this fourth component *Information.*

6. Interpretation and discussion of the district differences

We now turn to the differences among the three regions. In the introduction we mentioned that Machakos substantially differs from other regions in terms of adoption of farm technology and socio-economic welfare. Since we want to compare the social capital stocks among the regions, the principal component weights estimated in Table 4 above are applied to estimate the index for each individual.

Table5: Descriptive statistics of social capital indices

	Kiambu		**Machakos**		**Meru**	
Variable	**Mean**	**Std.Dev**	**Mean**	**Std.Dev**	**Mean**	**Std.Dev**
Association	2.34	1.57	4.11	2.44	2.60	1.60
Trust	4.26	1.37	4.49	1.90	4.31	1.58
Neighbour	0.96	0.37	0.92	0.41	1.08	0.24
Information	3.34	3.47	2.97	2.61	3.01	2.69

Table 5 presents district average for each of the social capital variables and shows that Machakos has a clearly higher mean score for ‘Association’ while the differences among the other variables are less pronounced. We need to test whether these differences are significant. A widely cited study of social capital and health of individuals used aggregate survey data responses in this manner (Kawachi *et al*., 1997). The results from the Kruskal-Wallis and Mann-Whitney tests are summarised in Table 6.

Table 6: District differences in social capital

	Kruskal-Wallis (p-value)	Mann- Whitney (p-value)	
		Kiambu	Meru
Associations	0.000*	0.000*	0.000*
Trust	0.500	0.313	0.303
Neighbour	0.000*	0.268	0.000*
Information	0.436	0.419	0.176

The Kruskal-Wallis test indicates that the difference in the means for 'Association' and 'Neighbour' between Machakos and the other two districts is statistically significant (χ^2=56 (2) df, P<0.0001). There is however no significant difference for 'Trust' and 'Information'. To compare Machakos to each of the two other districts individually we use pair-wise Mann-Whitney tests. The results are similar except that when it comes to 'Neighbour' the difference is only significant with respect to Meru and not to Kiambu. For this variable it is worth noticing that Machakos has the lowest value and not the highest, which was found in Meru.

We now turn to a discussion of the first principal component, which is not only the one that picks up the highest proportion of variation but also the one where the differences are clearest among the various districts: *the tendency to associate*. Reconsidering the individual components of 'Associations' fills in more of the details on the noted differences. Table 7 presents some background data collected together with the variable C2 by region together with more detailed information from the survey not used earlier. There are striking differences among the districts when it comes to association membership and key associations.

Table 7: Membership in associations (percentage)

C2.Number of associations	Kiambu	Machakos	Meru
a) None	9	3	10
b) One	56	24	46
c) Two	31	40	31
d) Three	4	33	13
C2.Most important association			
Merry-Go-Round (rotational savings and credit associations)	48	27	47
Agricultural group	13	19	12
Religious group	23	32	20
Other general welfare groups (burial, village, football, political, women etc.)	16	22	20

The survey shows that membership varies by district. Kiambu had most farmers belonging to only one association (56 percent) and the smallest proportion belonging to three associations (4 percent). In contrast Machakos, had the largest participation with 33 percent of households belonging to three associations, and the smallest proportion that did not belong to any single association (3 percent). In line with conventional wisdom, the average number of association meetings is highest in Machakos. The higher density and diversity of networks in Machakos imply more network resources than the other two districts. According to Burt (1992), the more the relations of this nature, the better for individual goal attainment. Just looking at the volume of associations is of limited value, because it does not say much about the resources that are accessed by the individual since some of the associations offer similar resources. There might be decreasing marginal returns from accessing basically similar resources from different associations. Hence, another interesting aspect is the diversity of groups, which does seem to be a bit higher in Machakos. In Kiambu and Meru almost half the memberships are in 'Merry-Go-Round' or ROSCAS, which are mutual savings and credit associations. Machakos has higher membership in both professional (agricultural), religious and other associations. Church organizations are known to provide not only spiritual guidance but material benefits as well, such as opportunities for interaction and support. They also instill a sense of shared values and norms among their adherents, teach worldly virtues such as love, patience, concern for others, and self sacrifice and bring individuals together to a cohesive and cooperative community. In terms of social capital it is possible that the links and trust forged in religious congregations are stronger than in other associations. People join associations for different purposes, but ultimately to improve their welfare. Different associations are also for obvious reasons rather distinct in this respect. Table 8 is based on the reasons for membership in the three most important associations, given by the household head.

Table 8: Reasons for being in groups (percentage)

	Kiambu	**Machakos**	**Meru**	**All**
None	18	21	12	17
Family welfare	45	40	63	49
Credit and Insurance	19	30	12	20
Others	17	9	14	13

Overall, ‘family welfare’ and a ‘safety net’ against unforeseen risks were the most important reasons cited for being in groups. Many other reasons were too diverse to be readily classified. Focus group discussions revealed that these were mainly to improve the households’ alternative income generating potential and purchase of durable assets. Provision of assistance during hardship and access to credit were important uses of the groups that we have summarised as the ‘credit and insurance’ motive. This appeared to be a particularly prominent motive in Machakos (30 percent). The presence of rotational savings and credit associations serve to close the liquidity gap, because the commercial banks generally reject smallholders due to the risky nature of their activities and their lack of collateral to secure loans. Focus group discussions reported that maintenance of close ties with groups was an important way to manage crises such as illness, deaths, school fees and price uncertainty. Such problems can be devastating for farmers dependent on agriculture, prompting them to establish groups whose assistance is based on reciprocal arrangements in case of an emergency. While there are no fees, all members are supposed to pay and provide labour in the event of another member’s death.

A puzzling observation in Machakos with the largest degree of association membership was the large share (21 per cent) of respondents who could not give any reasons for belonging to an association. This result is odd, but might be due to ‘association fatigue’ beginning to set in within the Machakos district. Naturally these are very dynamic processes and it is possible that Machakos started early with a high degree of association membership and that the population, although having reaped benefits, is also beginning to grow tired of spending too much time at meetings. However, our present data do not allow us to test this possibility.

Table 9 provides information on the proportions of households that reported individual benefits from group membership. The most common benefits were the sharing of labour and information, while sharing cash was less common in all three districts. A notable proportion indicated that they receive no benefits. Interestingly, Machakos was the community where the largest number of members felt they did not receive any benefits (58 percent), despite having the largest proportion of households in associations.

Table 9: Benefits from groups (percentage)

	Kiambu	Machakos	Meru
None	49	58	48
Cash	7	9	8
Information	20	15	22
Labour	24	18	23

Focus group discussions revealed that this could be due to temporary conflicts in the cooperative movement. There had been leadership wrangles among the societies and delayed payments for crop and milk deliveries. The results might therefore have been partly temporary, but there are also at least two other possibilities. First, it could be a selection effect: since Machakos has higher association participation, there is a larger number of 'passive' members who have a hard time explaining their memberships (see above). Second, it could also be that we are witnessing a backlash. If many people joined associations in Machakos in the past (possibly because of social pressure) the success might eventually generate some fatigue and resistance. Another plausible explanation is the insight provided by Collier (2002) that social interactions may fade while the 'capital' aspect lingers on. All of these issues touch on the broader issues of whether social capital is stable over time and whether indeed it is endogenously given by development or exogenously given by historical conditions. Unfortunately these fundamental questions are very hard to answer and it seems they would require at the very least, data on social capital (and other variables) over time which we do not have.

The wide variations in levels and forms of social capital among regions require an explanation. In our post interview group discussions, we gathered information on participant history of associational ties. Machakos is striking for two major reasons that are of particular importance to this study. First of all, the population is very homogeneous and comes mainly from the Akamba culture. They are known to have strong cohesion and have a long tradition of working together (referred to as Mwethya). Regular contacts through various groups and cooperative movements enhanced the principle of collective action. In general the ability to sustain such collective action is important because better prices can be negotiated on the basis of volume. Fluctuating market prices can offer tempting opportunities for individuals to obtain better prices by violating their commitments to the group and selling elsewhere. Lack of commitment on the part of farmers was frequently mentioned to be increasing, suggesting that maintaining collective action was not easy. In the past the collective action problem was handled in a variety of ways in Machakos. Churches and political leaders constantly reminded members of the importance of solidarity and mutual benefits of collective action. Several cooperatives built commitment by running other social development programmes. Although this is a non-economic activity it was seen to be community wide in terms of inculcating values and tolerance. These techniques appeared to have worked better in Machakos than other areas suggesting that strong leadership could be partly responsible.

Additionally, farmers in Machakos initiated modern agriculture quite early and already in the 1950s soil erosion was severe and caught the attention of many researchers as witnessed by the debate (Tiffen *et al*., 1994). They were also hit by a series of unusual and unfortunate weather events, which provoked famine that also gained attention since this was close to the capital Nairobi. Information on these events was passed on to the younger generations through the women's groups. Such historical ecological experiences are important in shaping farming decisions. These women's groups act as a 'library of information' on how to cope with dynamic change in complex systems both temporally and spatially. In that way 'associations' help connect the present and the past. Such ecological information is crucial to help understand qualitative changes in complex systems as a means for improving the community's chances of survival. This view is consistent with adaptive management studies documented by ecologists (see Holling, 1978). Lastly, participants mentioned the role of religious institutions in reinforcing community cohesion. It was noted that values such as respect for each other, honesty, sharing, reciprocity and humility are enhanced. These were viewed as key ingredients for the success of local institutions.

Patterns of labour market participation may also impact social capital. The apparent decline of social capital in Machakos can be explained by young people now turning away from agriculture and into new businesses or employment. There are new employment opportunities offered by expansion of Export Processing Zones (EPZ) occasioned by the new US Africa Growth Opportunity Act (AGOA).

Both Kiambu and Meru have different social structures that do not favour collective action from associations. For instance, in Meru, horticultural producers collectively bought seed from a private horticulture company, but sold their produce individually to the company. They complained of problems with unfair competition amongst each other to the advantage of the company. In contrast, in Machakos the cooperative or association maintained seed exchange networks among them and hence were always assured of a supply of quality seed and then sold their produce collectively.

7. Conclusions

The importance of financial, human and natural capital for economic development is well known. In this study, we explore the somewhat vague set of characteristics called social capital. We recognise the need to have specific dimensions of social capital based on firm economic theory. Social capital may enter into the production and utility functions at the individual and collective level by facilitating joint production as well as the exchange of labour, credit and information. The use of principal components analysis did not support the creation of a single measure of social capital, but four readily distinguishable and interpretable measures namely the tendency to form '*Associations*', the existence of '*Trust*', cooperation with '*Neighbours*' and a fourth factor related to the flows of '*Information*'. Our findings concur with those of Haddad and Maluccio (2003) who found similar factors (except information) as determinants of economic outcomes in rural South Africa.

There is evidence confirming that Machakos is different, in particular with respect to higher association membership and diversity. This result is similar to Isham (2002), who found regional differences in similar social capital measures and their impact on fertiliser use in Tanzanian villages. Our findings agree with other studies (like Narayan and Pritchett), showing that heterogeneity of group membership is an important factor behind differences in economic outcomes. These results support the idea advocated by others (Putnam, (1993); Narayan and Pritchett, (1998); Isham, (2002); Haddad and Maluccio, 2003) on various dimensions of social capital. It is possible that Machakos originally had more churches and ethnic homogeneity and that this eventually paved the way for more active associations and a culture of trust, which turned out to be the most important forms of social capital. Alternatively, it could be that Machakos had special cultural predispositions and more formal associations that are actually better for economic development.

A policy conclusion of this paper is that there are efficiency and equity arguments for intervention geared at promoting the accumulation of social capital. One policy response would be to increase the tendency to associate by building or strengthening local community networks like churches. Another would be to encourage church attendance by providing greater tax incentives for tithing. Yet another would be to teach 'service learning' in schools and take measures to facilitate mutual trust promoting community self help through mutual volunteering.

However, some caution is necessary. Policy recommendations are difficult for the following reasons: First is the apparent importance of long-standing historical and cultural factors in driving social capital, which suggests it may not be easily susceptible to policy intervention. Second, there is a need for improved measurement of social capital and for more research on its responsiveness to policy intervention. To conclude, we know that social cohesion is readily destroyed and hard to build, which implies that social controversy can be very disruptive. As for the grand debate between the 'Boserupian' and 'Malthusian' views we must be humble and say that many more studies are needed. This one does show that Machakos was special, but on the other hand, not different enough to preclude dramatic improvements also in other similar regions. This will however require determined policy making efforts that need to be founded on more research.

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Appendix
Survey questions used to extract social capital information.

Social Capital

Associations

In this section, I would like to ask you about the groups or organizations, networks or associations to which you or any members of your household belong. These could be formally organized groups or just informal groups of people who meet regularly to talk or do an activity.

C1Do you or any member of the household belong to any organisation or association?
1.YES………….. 2.NO……………..[Read out the possible types from the list] (Farmers group, Traders and Business Association, Church, Soccer Club, Agricultural club, Credit/Finance group, Merry-Go-Round, Village committee, Burial committee, Political group, Cultural group, Water group, NGO, Civic group, and so on).

C2.Of all the groups to which members of your household belong to, which are the three (3) most important to you and/or your household?
a) b) c)

C3.How many times in an average month did anyone in the household participate in each of these groups' activities, e.g. by attending meetings and group work?

C4. How much money, time or goods did your household contribute to the group last year?
4a **Money** (amount Kshs) 4b **Time** (hours) 4c **Goods** (value Kshs)
Group1: a) b) c)
Group2: a) b) c)
Group3: a) b) c)

C5. What are the two main benefits from joining the groups?
For example improved household access to livelihood and access to services, important in times of emergency, beneficial to the community, enjoyment/leisure, social status/self esteem, others (please specify).
Group1: a) b)
Group2: a) b)
Group3: a) b)

C6. Does the group help your household with any of the following services? 1 YES 2 NO

	Group1	Amount	Group2	Amount	Group3	Amount
Agricultural inputs (seed, pesticide, technical advice etc)						
Artificial insemination services						
Credit/ savings services						
Soil conservation advice/ information						
Information on crop prices/market opportunities						

Personal Friends and contacts

T1. About how many close friends do you have these days? (These are people you feel at ease with, can talk to about private matters, or call for help)…………

T2. If you suddenly needed a small amount of money [Enough to pay for expenses for your household for one week], how many people beyond your immediate family could you turn to?
a) No one b) One to two c) Three to four d) Five or more people (Please tick one).

T3. Suppose you suffered a serious economic setback, such as crop loss. How many people could you turn to for help in this situation beyond your immediate family?
a) No one b) One to two c) Three to four d) Five or more people (Please tick one).
T4.In the past one-year, how many people with a personal problem have turned to you for assistance? ……………
T5.If so, please state the value/ amount ……………Kshs.

Neighbourhood Relations

N1. Have you during the past year assisted anyone with significant amount of tools? (Jembe, Fork, Hoes, Wheelbarrows, Spades etc) 1. YES… 2. NO…
N2. Have you or household received such help? 1. YES ……… 2. NO………..
N3/4.If a community project does not directly benefit you, but has benefits for many others in the neighbourhood, would you contribute time or money to it?

TIME	MONEY
a) Will not contribute time [1]	a) Will not contribute money [1]
b) Will contribute time [2]	b) Will contribute money [2]

N5. In the past year, have you worked with others in the community /village to do something for the benefit of the community? 1. YES 2. NO
If Yes, please state the activity…………………….

Sources of Market Information

I1-3.What are the three most important sources of market information (jobs, price of good or crops etc)?

a) Community centres, b) relatives, friends, neighbours, c) Radio, d) Television e) Community leaders, f) NGOs g) Business associates, h) Groups/Associations, i) Government agents, j) Internet, k) National newspapers l) Others.

I4-6.What are the most important sources of information about what the government services (such as agricultural extension, tree planting week, family planning etc)?
a) Community centres, b) relatives, friends, neighbours, c) Radio, d) Television e) Community leaders, f) NGOs g) Business associates, h) Groups/Associations, i) Government agents, j) Internet, k) National newspapers l) Others.

CHAPTER 3

Social Determinants of Soil and Water Conservation in Rural Kenya

Wilfred Nyangena[†],
Department of Economics,
Göteborg University,
SE 405 30 Göteborg, Sweden.
(Email: wilfred.nyangena@economics.gu.se)

Abstract

Soil erosion is a major environmental problem and threat to rural development in Kenya. Numerous attempts to address the problem have apparently had little success. There are however some districts that have been very successful, notably Machakos. In this study we search for the factors that determine successful development in soil conservation such as social capital, human capital and market integration. One of our main results is that social capital measures are significant determinants of investment in soil conservation. A better understanding of the relevant mechanisms is essential for developing policies targeting improvement in natural resource management.

Key words**: Social and economic factors; Random effects probit; Soil conservation; Kenya.**

JEL Classification**: Z13, Q10, Q16&O13.**

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1. Introduction

Many parts of Kenya experience severe soil erosion (estimated at 72 tons per hectare per annum, by de Graff, 1993). Soil erosion contributes to low and declining farm productivity that can profoundly affect poor farm households with minimal economic margins. There are also downstream effects such as water pollution, sedimentation and siltation of water bodies, disruption of aquatic ecology and destruction of road infrastructure. Finding ways to reverse these trends is an urgent need in Kenya and neighbouring countries.

Alarmed over these threats and in particular the impacts on land productivity, policy makers have sought to encourage investment in soil and water conservation (SWC) technologies. A wide variety of SWC approaches have been initiated in Kenya (Hudson, 1995; Pretty, 1995). In the 1930s measures included forced culling of livestock, compulsory labour to construct terraces and prohibition of farming on steep slopes. Frustration with farmer indifference led the government and donors to stimulate adoption of SWC technologies by offering various inducements aimed at soil conservation. Typically, cross slope technologies such as terraces, infiltration ditches and bunds have been promoted. The goals of these projects were to raise farm production and incomes, while reducing degradation. The incentives included input subsidies and technical assistance for the construction of SWC structures. Persuading farmers through economic incentives is believed to be a solution to minimize land degradation. Success as measured by adoption has however been very limited because the altered practices are either abandoned or neglected once the subsidies and other support are terminated (Lutz *et al*., 1994, Kerr *et al.*, 1996). Many reasons have been cited for this fact, including the coercive methods that may have contributed to soil conservation resentment. Furthermore, the vast investment in soil conservation may have failed because of the exclusively technical definition of activities without regard to local farming conditions.[1]

[1] For instance, the width of terraces must be sufficient to allow for easy turning at each end since farmers use oxen for cultivation.

Despite the long history and inclusion of economic incentives, the overall performance of soil conservation programs is mixed. Some regions have performed well while others are dismal and the reasons for success and failure are not well understood. For instance, in the 1950s the Machakos region was a disaster characterised by soil erosion, poverty and low crop productivity (Tiffen *et al.*, 1994). It became famous as an early example of the poverty-resource link that we now witness in many places. A combination of factors is taken to be causing this land degradation, including increased population pressure on natural resources, deforestation caused by firewood demands, and overgrazing resulting from overstocking. This is generally viewed as evidence of the vicious cycle through large families, high discount rates, myopic planning and so forth. This integrated process of poverty and increased resource degradation has been described as 'the downhill spiral' that leads to a poverty trap (Cleaver and Schreiber, 1994). Machakos is often presented as key evidence that this situation can be transitory. Today it presents an interesting case study of successful rural development. Soil erosion has been drastically reduced and the region is one of the best terraced in Kenya (Tiffen *et al.*, 1994; Zaal and Oostendorp, 2002). It appears, among other things, that reductions in soil erosion were influenced by the presence of technical assistance promoting SWC and market access to Nairobi, which favoured high value cash crops and thus increased the value of soil conservation investment. There is much speculation behind the transformation. The debate remains unresolved and is still highly controversial (Barbier, 2000).

Given the lack of consensus and relatively few successful examples, the purpose of this paper is to compare Machakos to Kiambu and Meru[2] (two other regions in Kenya) to identify what factors explain the performance of Machakos. We hope thereby to shed light on whether Machakos is different and how this success can be emulated. We will explore the underlying determinants including human capital (education, age), biophysical characteristics (slope, erosion status), tenure characteristics (affecting ability to finance investments and incentives to invest), and infrastructure and access to markets (affecting prices of inputs and outputs). As a more novel ingredient, this study also places emphasis on one additional mechanism that may contribute to the

[2] These areas in Central and Eastern Kenya respectively show a deepening environmental degradation.

understanding of SWC adoption. This mechanism is 'social capital' which embraces the qualities of people and organizations that influence the responses of people to economic opportunity (Abramovitz and David, 1996). The success of Machakos could partly be an outcome of favourable social arrangements. An understanding of the transformation will ratchet up the pace of development, because if one knows what determines success and what causes failure, and if one can influence these factors, then significant improvements can be made in soil and water conservation.

Recent theoretical work has emphasized the interaction among social arrangements, incentive structure and growth (Fershtman, Murphy and Weiss, 1996). Similarly, Pretty (2003) documented the growth of social capital as evidenced by group activity in a wide range of natural resource management sectors, including watershed management, integrated pest management and farmer experimentation. It is not immediately obvious that investment in soil and water conservation requires social capital. However, the 'Machakos miracle' suggests that collective action is needed to: implement soil conservation on individual farms (e.g. through labour exchange, marking out contours, credit provision, risk sharing); raise awareness of soil erosion and conservation; and provide farmer led, group based training in soil conservation, maintenance of links with government agencies etc. Let us now turn to these activities in more detail.

First, social networks can foster cooperative behaviour and ease coordination problems (Krishna, 2001; Bowles and Gintis, 2002). The construction of soil conservation structures is complex and demanding in terms of labour intensity and technical skills. Local farmers are poorly equipped to deal with these problems since they have little formal training and little access to good agricultural extension services. These constraints make soil conservation unattractive particularly for less endowed households. Farmers rely on labour pooling to overcome labour shortages particularly during peak seasons, especially those farmers who are pressed to hire labour. Moreover, making decisions on appropriate soil conservation structures coupled with related concerns of crop choice, farming skills and knowledge of technology are very complex and worsened by farmers' extreme poverty. In these circumstances farmers tend to observe, seek information, borrow and learn from the farming methods of their friends.

Second, formal credit markets do not function well in agricultural societies due to high information, monitoring and transaction costs, lack of collateral and moral hazard problems (Stiglitz and Weiss, 1981). One would expect land to be collateral, but due to non-tradability in developing countries this is not the case. The lack of credit discourages investment in productive activities like soil conservation. Under these conditions, strong social capital can facilitate the pooling of finances, which can then be invested in soil conservation.

Third, benefits from soil conservation investments are uncertain, and materialize with a lag. Faced with no possibility to save or borrow, as is typical in rural low wealth societies, investment is made at the expense of current consumption (see for example Hoff, Braverman and Stiglitz, 1993). Under these circumstances, social ties through support networks and reciprocity norms fill the gap in consumption smoothing. Given that these and similar sharing arrangements have been practiced over the years, they can be viewed as implicit insurances. An example of this sharing mechanism is alleviation of food insecurity through social networks. One's level of assets and food security determines the degree to which one discounts future gains. Those who possess more endowments will place a higher value on the long-run benefits produced by conservation investments. This is because they are less constrained by food insecurity and shocks undermining the ability to meet basic food needs, compared to the very poor (Shivley, 1997). Similarly, since farmers operate under imperfect and asymmetric information, one practical aspect of social capital is the ability to provide information channels that may be relevant for SWC investment decisions.

Finally, while SWC technologies are employed on individual farms, the techniques operate at the landscape level, thereby making collective action particularly relevant. For instance farm technologies like terracing (or pesticide application) require widespread and coordinated adoption in order to be effective. A technology that requires 10 hectares could be internalised and adopted within a single farm in some areas, but requires coordination of hundreds of farmers in our study areas. Technologies that operate on a watershed scale are more feasible where traditions of cooperation are strong.

Again, the success of SWC investment requires cooperative behaviour among farmers. For example, run-off causing soil erosion does not respect boundaries. This means that even if a farmer adopts SWC measures, he may still face damage coming from neighbouring farms where no control measures are taken. Another context of cooperative behaviour involves farmers sharing implements, exchange information on construction and on the proper layout of SWC structures among farms. In addition, construction of SWC structures demands a lot of labour. Farming households collaborate in labour exchange in order to overcome these labour constraints. These examples suggest a complex mixture of public, club and private goods and hence it is easy for one to benefit without payment, in effect to free ride. Social institutions based on trust, reciprocity and rules for behaviour can mediate this kind of unfettered private action. The broad agreement is that social interactions affect economic outcomes like SWC investment. The next question is to understand these mechanisms better.

Many questions about the determinants of adoption remain unclear. Early studies focus on individual and plot characteristics, see Feder *et al.*, (1985) for a detailed survey. Economic research on farm technology adoption has partially addressed the issue of how social factors can affect adoption (Foster and Rosenzweig, 1995). These studies are based on the idea that neighbouring households are members of a social structure in which they exchange information on agricultural practices. However, none of them tests how social structures that vary from region to region may affect farm technology adoption. If all regions receive the same level of assistance, why then should results vary so much from one locality to another? It is claimed that more cooperative groups caring for each other will achieve better outcomes, while those with lower levels of cooperation will achieve less. Non-economic research suggests that the characteristics of social structures are critical determinants of adoption (Rogers 1995). However, social capital has not been measured in any satisfactory way yet, but has rather been addressed in an ad hoc manner (Paldam and Svendsen, 2004).

The literature on social capital has come to the fore with the much-publicised work of Putnam (1993). There is a small but well-established literature on this subject from developing countries that uses survey methods. Most of them stress indicators of trust and social participation on a range of outcomes: economic growth on cross-country studies (Knack and Keefer, 1997), household incomes in Tanzania (Narayan and Pritchett 1999) and greater use of modern agricultural inputs in Tanzania (Isham, 2002). In another context social capital serves to mitigate effects of individual-specific economic shocks faced by poor households (Carter and Maluccio, 2003; Fafchamps and Lund, 2003). A system of social exchange is an integral ingredient of a rural household's risk reduction and coping strategies. Similarly, social capital is needed for mutually beneficial collective action and coordination (Krishna 2001; Krishna and Uphoff, 1999). Narayan and Pritchett (1999) found higher group membership associated with higher household income in Tanzania. In the study of 60 villages in India, Krishna found high stocks of social capital, yet this alone did not translate to community development.

In any economic model, the decisions of one agent will be influenced by the behaviours of others. Inclusion of community social interactions is not straightforward. Positive effects of group behaviour on individual behaviour can be interpreted as social effects, while they are due to characteristics common to all villagers. For the individual farmer, social capital in the form of good relationships with others is a private asset he can draw on as capital. In addition to this, there are social or public good effects of social capital. Not only am I better off if I have a good deal of social capital, but I also benefit indirectly by living in a society where everyone has ample social capital, since it will lead to a trusting and entrepreneurial atmosphere conducive for investments and growth. These features, however, may pose some problems. First, there is an identification problem in the analysis of contemporaneous behaviour also known as the reflection problem, Manski (2000). The reflection problem arises because the behaviour of the farmers in a village affects the behaviour of an individual farmer in that village but the behaviour of that farmer affects village behaviour, thus creating simultaneity bias (Durlauf, 2002). Following Manski, (2000) and Durlauf and Fafchamps (2004) we tackle the problem of identification by including a lag in the transmission of social effects. We exclude the observation of individual i from his average village group.

We show that some of our indices of social capital and economic variables influence investment in soil conservation. The finding suggests that contemporary research in soil conservation seeking to explain the differences in adoption should think about some of the issues that originate in social arrangements. Such an assessment can serve as a useful guide for the design of appropriate and sustainable SWC programmes and support services. Policy makers may use information obtained from this study to enhance adoption of SWC measures. Many believe that adoption of SWC measures will reduce soil erosion and increase land productivity and the incomes of farmers in Kenya. To our knowledge this is the first paper to test how social structures that vary from region to region may affect soil conservation in Kenya.

Section 2 displays the data and Section 3 presents the estimation strategy. In Section 4 we present results that incorporate the effect of biophysical variables, human capital, infrastructure and social capital. Section 5 concludes and draws policy implications of the findings that may help guide the design of appropriate and sustainable SWC programmes and support services.

2. Data

The data used in this study were collected in the Machakos, Kiambu and Meru districts from January through April, 2003. The survey contains detailed information on household demographics, human capital and land under cultivation, assets, access to markets and infrastructure, community variables and plot level[3] agricultural practices (crops and acreage, output, prices, SWC types etc.) for the 2001/2002 production season. There are also many questions that have been used in earlier work[4] to construct indices of social capital. Section 2.1 will present the raw data used in this paper while the methods and results on social capital that are also used as data in this paper are presented in section 2.2.

[3] A plot as used in this study is a contingent piece of land that has been cultivated with a specific crop or crop combination for which the farmer can measure the inputs and outputs.

[4] See Chapter 2 for the questionnaire and references.

2.1 Descriptive statistics

The descriptive statistics on household and plot characteristics for the study regions are presented in Table 2. A number of previous studies on soil conservation have employed dichotomous variables (Feder *et al*., 1985; Place and Hazell, 1993; Shiferaw and Holden, 1998) to represent the decision status. Individual plot-level adoption models assess adoption in terms of the likelihood that a farmer, with given social and economic characteristics, will adopt a given technology. In our case the dependent variable is '*Conserve'*, a dichotomous variable taking a value of one if there were a physical soil conservation structure on the plot and zero if there were none during the last five years**.** The structures included bench terraces, fanya juu and infiltration ditches. Overall, the proportion of plots with SWC was highest in Machakos and lowest in Kiambu. Previous studies have indicated that prior adoption was highest in Machakos (Tiffen *et al.*, 1994) which is observed in our data as well.

The choice of covariates in the model is based on a literature review of the determinants of adoption, which have found some of these variables to be significant (Ervin and Ervin, 1982; Feder *et al*., 1985; Besley and Case, 1993; Shiferaw and Holden, 1998; Lapar and Pandey, 1999, Gebremedhin and Swinton, 2003). Topographic and farm characteristics may influence land investment decisions. The proportion of highly eroded plots does not vary between Kiambu and Meru. Equally there is little variation in the proportion of lowly eroded between Meru and Machakos. These are the farm characteristics that may influence adoption of SWC measures. The proportion of plots located in the upper slope is roughly comparable across the regions. However, there is a remarkable difference in the proportion of plots located in the mid slope. It is highest in Meru and lowest in Machakos. The position of a plot on the slope profile also known as catena is an important indicator of the erosion potential as well as soil conditions (Lapar and Pandey, 1999). On a typical slope the steepest region is found mid slope. Thus, one would expect that the marginal productivity loss due to erosion from a plot in the middle catena with fertile topsoil to be highest in the short term. Hence, plots on the mid slope/catena would be expected to have more conservation investments because of the higher slope compared to those on the lower catena.

Household characteristics include years of education, age (linear and quadratic term) and gender. These variables reflect human capital of the household. On average the youngest household head is found in Meru. The mean number of years of formal education is lowest in Machakos for household members age 16 and over. The largest proportion of male-headed households is found in Meru, while it is roughly comparable in the other districts. Household demographic characteristics will also affect conservation investment decisions and outcomes by imposing some costs. The major costs are labour costs for initial construction of the structures and maintenance, and an opportunity cost of the land lost to construction structures. To capture the effects of household age composition, we include a dependency ratio which is equal to the number of persons who cannot work [under age 6 and above 65] divided by the total number of household members.

Consistent with areas of high population densities, land holding per capita is almost uniform across the study regions. The proportion of households receiving remittances is highest in Machakos and lowest in Meru. Indicators for access to markets differ. Farmers in Machakos travel the farthest distance to sell their produce, while the distances in Meru and Kiambu are comparable. In terms of bus fares to markets for farm inputs (typically the divisional centres), the mean fare is highest in Kiambu and lowest in Meru. Compared to Kiambu and Meru, Machakos cannot readily be described either by high tenure security or by shorter distance to markets. Although poor land tenure has been blamed for the relatively low investment in SWC, we find the situation in Machakos confounding. One would expect uncertainty in tenure to weaken farmer investment incentive especially for long-term structures. Also, poorly defined land rights may reduce production since farmers are unable to access credit without collateral. However, it may also be the case that investment in SWC is a way to secure the rights to the land. As we see from Table 2, it is not immediately obvious which differences in the descriptive statistics might explain the observed differences in adoption. Given the polarisation of views on SWC adoption in Kenya, it is particularly interesting to search for alternative plausible influences. This is basically why we turn to a regression model.

Table2: Descriptive statistics of variables

Variable	Definition	Kiambu		Machakos		Meru		All	
Dependent variable		Mean	Std.dev	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev
CONSERVE	Presence of SWC structure on plot	0.53	0.64	0.67	0.44	0.64	0.43	0.57	0.49
Farm Characteristics									
HIGHLY EROSION	Proportion of highly eroded plots	0.23	0.42	0.06	0.24	0.19	0.36	0.19	0.39
MODERATE EROSION	Proportion of mildly eroded plots	0.04	0.09	0.25	0.42	0.13	0.09	0.12	0.11
LOW EROSION	Proportion of lowly eroded plots	0.74	0.44	0.65	0.48	0.67	0.41	0.69	0.34
UPPER SLOPE	Plot located in upper slope=1, Else=0	0.39	0.48	0.37	0.47	0.35	0.48	0.37	0.48
MID SLOPE	Plot is located in mid slope=1, Else=0	0.31	0.46	0.29	0.46	0.48	0.50	0.35	0.47
LOW SLOPE	Plot is located in lower slope=1,Else=0	0.29	0.45	0.33	0.49	0.16	0.37	0.27	0.41
Tenure Security									
HIGH	Complete rights=1, Else=0	0.71	0.45	0.12	0.33	0.66	0.47	0.51	0.68
MEDIUM	Preferential use rights =1, Else=0	0.16	0.37	0.62	0.48	0.15	0.35	0.21	0.41
LOW	Limited use rights=1, Else=0	0.13	0.34	0.25	0.44	0.19	0.39	0.15	0.36
Behavioural/Household Characteristics									
EDUCATION	Years of schooling for all above 16	7.6	2.56	6.14	2.28	6.77	2.27	7.16	2.48
AGEHH	Age of the household head in years.	52.8	14.3	55.13	10.61	47.91	12.51	51.9	13.5
DEPENDENCY RATIO	Ratio adults to < 6 and > 65 in family	0.32	0.20	0.31	0.22	0.28	0.20	0.31	0.21
HIRED LABOUR	Share hired farm workers	0.31	0.57	0.08	1.29	0.06	1.43	3.2	1.5
REMITTANCES	Receipt of remittances=1,Else=0	0.69	0.46	0.90	0.30	0.61	0.95	0.77	0.42
PER CAPITA LAND	Share of land area to family size	0.30	0.32	0.29	0.27	0.26	0.18	0.28	0.27
PERENNIAL CROP	Perennial crop on plot=1; Else=0	0.28	0.45	0.31	0.46	0.41	0.49	0.32	0.47
PRIOR ADOPTION	Proportion of previous adoption (%)	0.31	0.18	0.69	0.25	0.51	0.36	0.51	0.23
Distance to									
PRODUCE MARKET	Mean walk time to nearest market (Min)	33.00	16.00	60.00	55.00	31.00	18.00	35.0	24.0
ADMINISTRATIVE HQ	Bus fare home to divisional centre (Kshs)	56.00	9.00	47.00	8.00	42.00	27.00	47.0	21.0
Sample Size (number of plots)									
ADOPTERS		183		44		93		320	
NONADOPTERS		162		22		52		236	

2.2 Social capital measures

Though social capital is recognized as being an important element of resource management, it remains a difficult issue to address empirically. The studies by Krishna (2001) and Narayan and Pritchett (1999) mentioned earlier are relevant to our study because they are based on a rural agrarian setting and because of the manner in which they construct their social variables. These studies ask questions[1] about the household's social relations, memberships in groups, participation in community activities, attitudes and values in settings similar to ours. Responses from these questions are combined to form quantitative indicators of social capital using factor analysis. The technique is a method of data reduction, which attempts to describe the indicators as linear combinations of a small set of underlying variables (Dunteman, 1994; Johnston and Wichern, 2002).

In Chapter 2 we had no a priori theoretical basis for choosing measures of social capital. Thus we let the data decide based on patterns of correlation. We sought variables designed to measure: (1) interactions with one another by borrowing small farm implements, risk coping strategies, discussing various local issues and learning from each other about SWC techniques; (2) working with neighbours and local participation in collective action activities; and (3) sources of agricultural market and public information. Most of the social capital literature specifically mentions trust as an important constitutive element. Unfortunately, we could not ask respondents the extent to which they trusted their neighbours due to its inappropriateness, evidenced during the design phase. Presumably however trust is both reflected by and built through activities such as borrowing money or food from non-relatives. Such activities would thus be more common in environments in which people trust one another and we are therefore using this as a proxy for trust. It turned out that many of the variables were highly collinear, so a principal components analysis (PC) was conducted to aggregate the variables into various indices. The analysis also uncovered patterns and associations by looking at loadings on variables across components of the variation. The loadings were used as weights yielding an overall component measure of social capital derived as a

[1] See World Bank: Social capital initiative. http://www.worldbank.org/poverty/scapital/index.htm

sum of the product of component scores.[2] In the PC analysis a component was retained as long as its eigenvalue was greater than one and four components were retained. To interpret the loadings or weights we set the criterion to 0.3 or more (See Chapter 2 for details). Since the data were collected at the household level, we compute indices at that level and then average the values to obtain a regional average index. Correspondingly, four distinct aspects of social capital were derived to create quantitative measures (constructs) of social capital, namely association, trust, community and information.

The indices will be used to assess individual and combined influence of various social capital variables at the regional level. The first component, which accounted for the largest amount of variation in the data set, regroups a number of variables relating to a measure of membership and degree of participation in local associations as well as participation in community projects. No membership at all was coded zero. These variables are all indicators of an individual's strong connections with neighbours. This factor was named 'Association' since that term captures the main essence of the variables captured. The second component interpreted as a 'trust' index, is based on three variables reflecting solidarity in reduction of adverse shock, lending of money, food and reciprocity. Interestingly, these first two indices approximate Putnam's (1993) now famous components of trust and civic engagement. Broadly speaking, the dominant features describing social capital are 'membership of voluntary organizations' and 'trust' (Glaeser *et al*., 2002).

In addition, the third component relates to results from the loadings on participation in the sharing of farm tools and assisting neighbours. It captures resident volunteerism and presence in the community. It goes beyond the first component capturing public participation among neighbours for a shared sense of community. Paxton (1999) reports similar findings on neighbours borrowing implements and participating in community matters. Lastly, there is a component reflecting how farmers collect information. It was created from sub-indices formed from counting and ranking households' most important

[2] If X_1, X_2…Xn are the original set of n variables, then a variable Y formed from a linear combination of these takes the form $Y= a_1X_1+a_2X_2+…+a_nX_n$ where the a_i's (i=1,2….n) are the principal component loadings or weights. The weights or loadings add up to one.

sources of information on crop prices, agricultural news and government news. This ranking was then reversed such that a household with all three sources of information was ranked first, and a household with only one was ranked last. Using such an ordinal measure may result in loss of valuable information if some source is better than others. The PC analysis showed a negative loading on community sources that resulted in some households having negative aggregates. Due to the low loadings of the variables in other components it was fairly easy to name this group 'Information' and a high value on this variable thus reflects the fact that the individual is well connected through a strong network of social contacts and has many different sources of information.

These four indices of social capital were used to evaluate the differences in levels of social capital among Machakos, Meru and Kiambu. Table 2 presents the descriptive statistics for our social capital indices, which will also be used in the empirical analysis.

Table2: Descriptive statistics of social capital indices

	Kiambu			**Machakos**			**Meru**			**All**		
Variable	Mean	Min -	Max	Mean	Min –	Max	Mean	Min -	Max	Mean	Min -	Max
Association	2.34	0	12.6	4.11	0	16	2.60	0	8	3.02	0	16
Trust	4.26	2	9	4.49	1	18	4.31	1.6	11	4.36	2	18
Community	0.96	0	1.1	0.92	0	1.4	1.08	0	1.2	0.99	0	1.4
Information	3.34	-4	13.5	2.96	-2.3	10.3	3.01	-3	10.2	3.11	-4	13.6

The sum of 'association' ranges from 0 (no membership) to 16. There are big differences between Machakos and the other regions. The mean of 'association' in Machakos was 43% and 37% higher than in Kiambu and Meru respectively. Our second indicator of social capital 'trust' it appears to be almost equally shared. There are, however, considerable differences in the range of the index. The maximum value of 'trust' is twice as high in Machakos as in Kiambu. Interestingly, Machakos ranks lowest with regard to 'community attachment' and 'information[3]' indices. We use these indicators to understand how social aspects of individual and community behaviour contribute to or detract from sustainable agriculture.

[3] The information index has a negative minimum due to the negative weight attached to communal sources of information, presumably seen as substitutes for other sources of information.

3. Modelling and estimation issues

There are many classes of models explaining soil management. Many emphasize the role of soil as capital and are consequently dynamic models. These models link and investigate the effects of economic and biophysical factors such as market imperfections, price incentives, soil depth and so forth on soil capital (see McConnell 1983; LaFrance, 1992; Goetz, 1997; Yesuf, 2004). While these studies show that economic and biophysical factors explain most of the variation, the role of social and economic factors in explaining soil conservation outcomes remains an important area of research. However, many empirical studies including this one only have a cross section of data from one point in time. In this sense the analysis is, therefore, a static one, but some aspects of dynamic optimisation can still be gleaned by comparing investments on individual plots.

Arguments have been presented above as to why social capital may affect SWC adoption decisions. However, despite these theoretical claims social capital remains a problematic notion on the empirical level. Farmer investment decisions are based on consideration of benefits and costs. Empirical models describing adoption of farm technology are based on the assumption that households choose to adopt when the present value of future net returns from adoption rise above the present value of future net returns from non-adoption. The effects of market distortions are reflected in higher input prices, which affect the profitability of agricultural production. Conceptually, social capital mediates costs through its influence on constraints and preferences (Zak and Knack, 2001). Individuals and regions endowed with social capital help to lower costs that go along with an increasing need for collective action and coordination among farms. In this context it shapes opportunities and constraints for farmers.

To highlight these points formally, let h denote the household and p plots within the household. The household makes a decision to invest in SWC on a plot as a function of observable and unobservable household characteristics as shown in Eqn. (1).

$$Y_{hp}^{*} = \beta' X_{hp} + \varepsilon_{hp} \qquad Y_{hp} = 1(\,if\ \ Y_{hp}^{*} > 0) \quad , \qquad (1)$$

where Y_{hp} is an observed binary (latent) variable indicating the household's decision whether or not to invest in SWC on a plot. The vector X_{hp} includes explanatory variables for observable household characteristics which influence the decision to invest in soil conservation. Lastly, β is a vector of coefficients to be estimated, and ε_{hp} is the error term assumed to be random.

The data set consists of multiple plots managed by a household, thus there is potential for correlation among plot observations to deflate standard errors and bias the estimated coefficients. An alternative method of estimation which accounts for such multiple plot level data is the random effects probit (Wooldridge, 2002). The random effects probit model assumes that the correlation between successive disturbances for individual plots can be reduced to a constant ρ (Butler and Moffit 1982). The relationship in Eqn (1) is modified to account for multiple plots as:

$$y^*_{hp} = \beta' X_{hp} + v_h + \mu_{hp},$$

$$\varepsilon_{hp} = \upsilon_h + \mu_{hp} \text{ and } \mathrm{var}[\upsilon_h + \mu_{hp}] = \mathrm{var}[\varepsilon_{hp}] = \sigma^2_\upsilon + \sigma^2_\mu. \qquad (2)$$

The correlation between two successive error terms for plots belonging to the same household is a constant estimated as in Eqn (3):

$$\mathrm{corr}[\varepsilon_{hp,}\varepsilon_{hp-1}] = \rho = \sigma^2_\mu \Big/ (\sigma^2_\mu + \sigma^2_v) \qquad (3)$$

The estimated correlation across plots is evaluated using a simple t- test (Greene, 1995). If the data is not consistent with the random effects model (no evidence of random effects in the model), the estimate of ρ will turn out to be negligible. The set of unobservable characteristics v_h are household-specific attributes that also influence farm investment decisions. The presence of household-specific but plot invariant characteristics lays the basis for using a *random-effects* estimator (Wooldridge, 2002). In particular there may be substantial variation in plot characteristics, within a household. This may create potential for correlation among the plots which may deflate the standard errors and bias the estimated coefficients. We also experiment with the alternative probit model.

An issue that may complicate the estimation process is linking previous conservation investment decisions to current economic and social capital variables, which may lead to biased estimates due to changing farmer characteristics. Our data cover soil conservation at various dates in the past whereas social and economic variables are current. The correct approach when using cross-sectional data is to establish relationships between current conservation indicators and social and economic determinants. Studies linking previous conservation investments to current economic characteristics found in the literature are flawed. Besley and Case (1993) and Besley (1995) are perhaps the best examples of accounting for the problem. Therefore, following Besley (1995) we use investments undertaken during the last five years. Although explanatory variables can change over time, it is highly unlikely that they would have changed dramatically during those five years. Moreover, in this study, identification is facilitated by the fact that our data is at the plot level. Since the adoption process has not yet reached equilibrium, our data allow us to solve the problem by including prior adoption (earlier SWC investments) for each plot.

4. Results

Table 3 reports the results for the decision to adopt SWC based on Eqn. (2). For comparison, we also present the alternative probit estimation results in which we use clustering to correct the standard errors due to the non independence of plots from the same household. The marginal effects of the explanatory variables were calculated at their sample means. The probit model is significant with a chi-square value of 216.32 and with 25 degrees of freedom. At a glance the results from both models are comparable and consistent with our expectations. We conducted statistical tests to determine the appropriateness of the random effects probit model. First, a test of the null hypothesis that the ρ coefficient is zero using a likelihood ratio test yielded a sample chi-square value of 63.5 at the 1% level of 21.7. The result suggests that the plot variance component is not negligible and consequently, the use of the random effects model is justified. In addition random effects probit models can be used to analyze data sets that include a single plot observation, Greene (2000). Second, a likelihood ratio test corroborated the superiority of the random effects probit over the probit estimation.

Table3: Estimated Coefficients of Probit and Random-Effects Probit Models of Probability that a Plot has SWC Investment

Variable	Probit Estimated Coefficient	Probit Marginal Effects	Random-Effects probit Estimated Coefficient	Random-Effects probit Marginal Effects
Social capital characteristics				
Individual level social capital				
ASSOCIATIONS	0.174*	0.022	0.219***	0.024
TRUST	0.193**	0.023	0.187**	0.036
COMMUNITY ATTACHMENT	0.236**	0.034	0.228*	0.021
INFORMATION	-0.341	-0.021	-0.377	0.035
Physical and farm characteristics				
Soil erosion status (ref LOW EROSION)				
HIGH EROSION	1.187	0.428	0.587	0.222
MODERATE EROSION	1.509	0.319	1.942	0.527
Location on toposequence(ref. LOWER)				
UPPER SLOPE‡	0.078*	0.065	0.044**	0.071
MID SLOPE‡	0.210	0.046	0.237	0.056
Perceived tenure security(ref. HIGH)				
MEDIUM‡	0.031	0.066	-1.019	-0.078
LOW‡	-1.193*	0.125	-1.124***	-0.118
Socioeconomic characteristics				
Human capital				
EDUCATION	-0.175***	-0.031	-0.154***	-0.099
AGE H/HEAD	0.134**	0.015	0.179**	0.022
AGE SQUARED	-0.012*	-0.002	-0.013*	-0.002
DEPENDENCY RATIO	0.354	0.172	0.734**	0.136
HIRED LABOUR	0.262	0.069	0.322	0.002
REMITTANCES	-0.523**	-0.108	-0.984***	-0.130
PER CAPITA LAND	-1.618***	-0.274	-1.669***	-0.163
PERENNIAL TREE CROPS‡	-1.145**	-0.212	-1.276***	-0.132
DISTANCE TO MARKET	-0.013***	-0.002	-0.017***	-0.028
BUS FARE TO DIVISION	-0.002	-0.005	-0.041	-0.014
PRIOR ADOPTION	-0.423*	-0.198	-0.481**	-0.215
District dummies†				
MACHAKOS (1=YES,0=N0)	0.973**		0.988	
MERU (1=YES,0=NO)	0.765*		1.121	
Constant	-1.485**		-1.345**	
Regression diagnostics				
Rho	-	-	0.927	
Log-Likelihood	-238.97		-237.31	
Wald Chi square (25)	216.32		95.34	
Nr of observations	556		556	

Legend: Partial derivatives are in probability units.
***,** and * significant at the 1%,5% and 10% level.
‡ For dummy variables marginal effect is a discrete change from 0 to1.
† Default district is KIAMBU.

The estimates suggest that some of our measures of social capital enhanced the likelihood of investing in soil conservation. Estimated coefficients for ‘Associations’, ‘Trust’ and ‘Community attachment’ are positively and significantly correlated with a higher likelihood of SWC adoption. The magnitude of impact upon SWC adoption is largest for Trust and Associations followed by Community attachment among social capital variables components. The result suggests that having more ties increases the likelihood of adopting soil conservation. A willingness to cooperate enhances collective action to provide public goods such as soil conservation. Associations describe group membership in voluntary organizations. These results may have either of the two following interpretations. First, they may indicate membership in cooperative societies, which are economically oriented and thus provide technical assistance and credit. Cooperatives pool resources to enhance joint commercialisation of agricultural produce, thus improving farmers’ margins. Membership in associations plays a number of different roles, including guarantors of informal loans through rotating informal credit schemes, the exchange of farm implements and information and the primary means through which extension services operate. They also provide a ready source of pooled labour under reciprocal arrangements. Members of a group may take turns in constructing terraces for each other. Informal credit is important especially in rural areas where formal credit markets are not well developed. Investment in soil capital or any other asset requires access to credit. Other studies have also found membership in local networks to be positively correlated with adoption of soil conservation (Gabunada and Barker, 1995; Swinton and Quiroz, 2003).

With respect to *Trust* the results suggest that people rely on each other to share resources and to pool risk, which are both critical for soil conservation investment. This can occur through two possible channels: First, in the context of land enhancing investment decisions, there is an assurance of consumption smoothing in the event of production shortfalls. This can be attributed to the safety net provided by friends in periods of economic need. The importance of this insurance is apparent for SWC investment since farmers undertake investments in which they have no experience or since it involves a shortfall in production that they are not familiar with. This transfer of resources and self-insurance mechanisms plays an important role in farm investment decisions by alleviating liquidity constraints. Finally, there are less coordination problems and related costs in SWC organization across farms, which reduce spatial externalities. Availability of *Information* may be a determinant of soil conservation investment even if it is not statistically significant at standard levels. Well-informed farmers are more likely to act rationally and have longer planning horizons.

We included two district dummies, Machakos and Meru, to control for regional differences. These coefficients are positive and significant which suggests that the explanatory variables in our model do not entirely explain why adoption of SWC is lowest in Kiambu. This result is not surprising and confirms a stylised fact in African adoption studies. Many studies have reported location specific dummy variables explaining the largest proportion of variation in adoption patterns. Arguably, our understanding of farmer adoption behaviour remains insufficient. Shifting focus to include social factors is one way to help get around to find the ultimate underlying factors. Several studies suggest the inclusion of factors such as social interactions at higher aggregation levels (Place *et al*., 2002).

Land tenure security captured as '*Low*' is significant and negatively correlated with conservation investment decisions. Tenure security gives the assurance of retaining the long-term gains from investment in land enhancing investments. This result is consistent with other studies on the impact of tenure security and soil conservation improvements (Besley, 1995; Shiferaw and Holden, 1998; Gebremedhin and Swinton, 2003).

The location of a plot on the toposequence is a significant determinant of SWC adoption. Estimated coefficient for '*Upper Slope*' is positive and suggests an increase the likelihood of adoption. This pattern is what one would expect given the need for SWC is greater at steeper slopes and lower in the lowlands. Steeper slopes are more vulnerable to erosion on average but also to land slides. The amount of soil that would be lost is determined by the rate of erosion, which is itself a function of the physical characteristics of the plot including location on a slope and the amount of soil present.[4] The coefficients of '*Soil Erosion*' status are positive but not significant.

'*Education'* has a negative and significant impact on adoption behaviour. This result does not support the expectation that more education should improve access to information and increase the understanding on benefits of conservation investments. The finding is consistent with Rahm and Huffman (1984) and Pender and Kerr (1998). A plausible explanation is related to time available for farm work. When more children go to school, increasing the average level of family education, they also decrease the amount of time available for soil conservation. This could also be due to a high opportunity cost of labour, since educated people can earn more in other tasks than farming. For such households, investment in land quality is in competition with the portfolio of other investments made or pending. This may partly explain why the impact of education on conservation can be negative, particularly if the positive effects from knowledge of conservation benefits are not known. More plausible, as shown by Weir and Knight (2000), is that household level education may only be important to the timing of adoption but less crucial to the question of whether a household ever adopts a farm technology. Early innovators tend to be educated and are copied by those who adopt later, thus obscuring the relationship between education and adoption.

There is a concave relationship between age and investment in SWC. A possible reason could be that younger and also stronger farmers have longer planning horizons and hence lower discount rates. Consequently, they are prepared to invest in soil conservation in spite of the lag before benefits are realized. This result is consistent with others in the literature (Lapar and Pandey, 1999; Shiferaw and Holden, 1998).

Households with *Remittances* are less likely to adopt soil conservation measures as indicated by the negative and significant coefficient. A possible explanation is that the extra earning opportunities reduce the time for farm work or relax liquidity constraints (World Bank, 1994). Additionally, they may have little concern about land quality due to their orientation towards off-farm activities.

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[4] Inclusion of a soil depth variable to control for land quality did not noticeably alter the coefficients or their standard errors.

Farmers with larger land holdings are less likely to invest in soil conservation result, and those with smaller farms per family size are more likely. Three plausible reasons can explain the finding. First, the critical issue of maintaining per capita food production demands induces intensification. Greater food demand by larger households suggests greater land scarcity, which may encourage careful land management. Alternatively, larger households have more labour to undertake construction of physical anti-erosion structures. This result is consistent with the Boserupian population driven argument for intensification (Tiffen *et al*., 1994; Templeton and Scherr, 1999). However, this result runs contrary to the neo- Malthusian hypothesis that a larger population will increase land degradation. In the Philippines it was found that small farm size was a barrier to undertaking land conservation investment (Shivley, 1999).

The presence of '*Tree crops*' discourages soil conservation investment adoption as expected. Tree crops provide soil cover, substituting soil conservation structures and controlling erosion at least as effectively as the run-off barrier (Young, 1997). The result suggests that agroforestry techniques are the preferred means of controlling erosion. Perhaps there could be synergistic benefits, only known to the farmer, of having a combination of tree crops and soil conservation structures. A similar finding of farmers not willing to make any other investments in agriculture has been reported in Kenya (Soule and Shepherd, 2000).

Distance to markets as an indicator of market related transaction costs and proxy for the quality of other public services was found to be negative and significant. Increased market access acts as an economic disincentive via reduced farm profitability and thus inhibits soil conservation investment. As a rational response, farmers faced with high plot to market costs commit less attention to agriculture. Improvements of market access and transport cost reduction investment enhance the adoption of land management practices in rural areas (Binswanger and McIntire, 1987; Pender *et al*., 2004).

The estimated coefficient of '*Prior adoption*' is negative and significant. This result is consistent with the hypothesis that farmers learn from others or that neighbouring farmers share some other unobserved determinants of adoption such as placement of SWC structures, economies of scale in input supply or output marketing. Similar results are reported for Tanzania in the case of crossbred-cow technology (Abdulai and Huffman, 2005).

5. Discussion and conclusion

Machakos is still a rather unique success story in agricultural intensification.. Our analysis shows that we can identify most of the factors explaining high SWC investment, and there are some variables that should be amenable to policy intervention. Our study shows that social capital is very important both at the individual and village levels. The natural response to the finding that social capital is important is to ask, 'How do we build social capital in regions where it is lacking?' Unfortunately, nobody has a handbook on how to go about it. This paper has argued that social capital can be added to a list of strong determinants, along with other economic variables. The role of social capital is to create avenues to finding solutions to collective dilemmas, improve access to technology and increase the benefits of investment.

Other results show that adoption of SWC varied with farm and behavioural characteristics. Tenure security is important as found in most studies. With better security of tenure, there is incentive to build terraces because farmers are able to recoup benefits that flow over a long period of time. In the case of insecure tenure, farmers face lower returns from soil conservation because of the likelihood of eviction before realization of full benefits. While increasing household education is important in Kenya, it does not necessarily solve problems of soil erosion. Like all potential investments, the expected benefits of all activities need to be compared. Education reduces small farmers' soil conservation efforts by increasing household opportunities to earn off-farm income. Those with higher education allocate their resources to better earning opportunities. However, such tradeoffs should not imply that education investment should not be pursued. Inclusion of elements of sustainable agriculture in the education curricula could help change attitudes towards sustainable land management. We found little evidence of an impact of access to administrative centres, but rather that access to markets is extremely critical for the adoption of SWC.

The implications for policy making are as follows: Many policies and programmes for rural development are supported by governments and development partners in natural resource management, agriculture, marketing etc., cooperating at the local level. In order to avoid the failures of past projects, it is important to subject these policies to rigorous tests of social arrangements. Planners for SWC should therefore identify local social structures and economic factors to guide their potential investments. Furthermore, government interventions promoting farm technology should deliberately target younger farmers.

Recent work has presented evidence that household economic performance and collective action are increasing with social capital (Narayan and Pritchett, 1999; Krishna and Uphoff, 1999; Krishna, 2001; and Carter and Maluccio, 2003). Linking this discussion to our findings indicates that social relations are very important attributes that farmers can employ to alter constraints. We complement the earlier which focuses on investment in sustainable agriculture literature since our data are derived from very poor households in a rural setting. We found that several dimensions of social capital were very important both at the level of the individual farmer and at the community level. Also, we incorporate social factors and important economic policy variables into the analysis. We demonstrate that relative improvements can be made in soil conservation even among poor people. Of particular importance are good infrastructure which reduces transportation costs and facilitates market access, tenure security and several dimensions of social capital that appear to correlate with the ability to work together in associations, to trust each other and to spread information.

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CHAPTER 4

Economic Assessment of Soil and Water Conservation Investments: An application to crop yield in Kenya

Wilfred Nyangena[†]
Department of Economics,
Göteborg University
SE 405 30 Göteborg, Sweden
(Email:wilfred.nyangena@economics.gu.se)

Abstract

Productivity gains from soil and water conservation (SWC) have empirical support in research stations. Previous empirical results from on-farm adoption of SWC have, however, shown a mixed picture. This study investigates the impact of soil conservation investment on farm productivity in three regions in Kenya. Using plot level survey data, we focus on land productivity on plots with and without SWC. We test the overall soil conservation hypothesis that increased SWC is beneficial for yield, as well as more specific hypotheses that SWC affects levels of inputs, returns from these inputs and crop characteristics. The results show a mixed picture where plots without SWC generally have higher yield values per hectare. Plots with SWC are significantly steeper and more eroded than plots without SWC. A more careful analysis of a two-stage random effects switching regression estimation comparing three SWC technologies to plots without SWC indicates that SWC increases the returns from degraded plots and sometimes from other inputs. A simulation exercise based on these estimations also shows that in most cases adoption has been beneficial for those who have done it and would be beneficial for those who have not.

JEL Classification: Q12, Q16, D61

Key words: Kenya, soil conservation, switching regression, rural households, yields.

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1. Introduction

Economists stress that increased agricultural productivity is an essential component of a successful rural development strategy for several reasons. First, rising productivity in food production makes it possible to feed an inevitably growing population. Second, surplus production can be sold in rural and urban markets generating incomes that boost domestic demand and other measures of well-being. Lastly, increases in food availability have beneficial impacts on the urban poor. Thus, policy makers see improvements in agriculture as critical to poverty alleviation and a precondition for economic growth, particularly in sub-Saharan Africa (World Bank, 2001).

Yet agricultural productivity is threatened by land degradation, defined as the decline in the land's actual or potential productivity (Blaikie and Brookfield, 1987). Soil erosion and nutrient depletion are two particularly common sources of declining agricultural productivity. Empirical studies have linked low and declining crop yield to the existence of soil erosion (Troeh *et al.*, 1991; Pagiola, 1994). Yields decline partly because essential organic matter and plant nutrients are lost. Eroded soils also suffer from moisture deficiency. Subsoil does not contain as much organic matter as topsoil and has smaller particle sizes, and is thus less permeable to water and less capable of storing moisture. In addition, as soil erosion exposes subsoil to cultivation, a rougher seedbed results in decreased seed germination (Townend *et al.*, 1996).

Although the decrease of agricultural yields to a certain degree can be compensated for by an increase in fertiliser inputs, this option is not available for many poor farmers. Living barely on subsistence level, most farmers do not have the economic capacity to use fertilisers. Also fertilisers, if not properly used, may be a source of negative environmental externalities such as pollution of surface and ground water.

In Kenya, soil erosion has been the subject of concern since the 1930s (Pretty *et al.*, 1995). Construction of physical soil and water conservation structures (SWC) was the first public response to the problem of soil erosion. The programs involved the construction of terraces using forced labour, but were soon abandoned with the 1963 independence. Alarmed by the adverse effects of continued soil erosion, the government established a programme to deal with the problem in 1974. An important feature of the program was the World Bank sponsored training and visit (TV) system of extension for soil conservation. This system was meant to include interactive farmer-extension participation coupled with intensive publicity and field and farmer demonstrations (Harding *et al*., 1996).

Another approach to stimulating adoption has been to give incentives to farmers. Incentives are in this case inducements from an external agency (government or donor) meant to motivate the local population individually or collectively to adopt SWC aimed at improving natural resource management (Laman *et al*., 1996). Politicians stress that these incentives should be available to all farmers because of the 'public good' nature of soil conservation. They view incentives as legitimate payments for off-site benefits of soil conservation enjoyed by society (Stocking and Tengberg, 1999). Given the persistence of land degradation, one conclusion that can be drawn is that these efforts have not been sufficient.

Policy makers recognise and are concerned about the adverse effects of soil erosion. The nature and extent of soil loss may suggest that current levels of adoption are socially and even privately inefficient. Although current practices may offer high short-term yields, they diminish the soil's future productive capacity. From a private agent's economic viewpoint, justifications for incentives for SWC include high short-term costs compared to economic benefits in terms of improved yields that may be delayed for several years before they are realized. Additionally, poor households lacking capital to finance productive investments may be unable to undertake lumpy investments like SWC, regardless of their expected returns. Other broader social concerns especially regarding yield decline and negative downstream externalities and the adverse effects on rural farm incomes and food supplies for consumers make soil conservation an important policy issue.

Although there is substantial research on SWC adoption (see e.g. Shiferaw and Holden, 1998, 2001; Chapter 3 of this thesis), there is a lack of information linking physical measures of SWC to productivity. Therefore, it could be of considerable policy interest to find an economic value by quantifying the impact of SWC adoption on agricultural production. Such an economic assessment should allow for an analysis of agricultural productivity of both adoption and non-adoption within the same farming system. Disentangling productivity differences between adopters and non-adopters is crucial for understanding household level responses to land degradation and for designing appropriate policy interventions.

Nonetheless, few attempts have been made to examine the effect of SWC on crop productivity in non-experimental settings. This neglect is probably due to methodological difficulties and weak data. An econometric evaluation to establish whether SWC techniques indeed offer higher returns and merit promotion is complicated. First, there is limited literature on the empirical evaluation of SWC projects conducted at the farm level. Farmers and policy makers have heavily relied on research station trials in order to establish how different farm technologies affect yield. Yet farm surveys consistently show that small farm holders fail to achieve the physical yields obtained in research stations (Evenson and Gollin, 2003). Second, adoption of technology is positively influenced by the current level of productivity (Feder and Slade, 1984); however, economic theory suggests that technology affects productivity. Thus, technology adoption and productivity appear to be jointly determined. Therefore, estimating a single equation *ex post* productivity with technology adoption as an explanatory variable is subject to simultaneity bias. Establishing *ex post* the true gains attributable to a technology, especially under farmer conditions, is thus a difficult proposition. This is an important empirical question, not only for understanding SWC promoting policies but also for poverty alleviation through agricultural growth.

Past work tries to clarify the relationship between investment in soil capital and productivity, but does not allow us to reach an empirical consensus. For example, Place and Hazell (1993) using data from Ghana, Kenya and Rwanda, found that land improving investments were insignificant determinants of yield. Hayes *et al.,* (1997) reported similar results for Gambia. In contrast, Byiringiro and Reardon (1996) examined the effects of soil conservation on farm productivity in Rwanda. They found that farms with greater SWC investments had much better land productivity than others.

Adgebidi *et al.,* (2004) reported significant positive productivity effects of soil conservation, but only after controlling for household specific constraints. These studies assume that the same set of factors equally affect both adopters and non-adopters. In addition, the limited number of studies dealing with the productivity implications of SWC adoption, and the conflicting results, warrant further examination of the issue.

The major objective of this paper is thus to estimate the impact of SWC on value of crop production per hectare with and without SWC. Barrett *et al*., (2004) suggested a switching regression model to evaluate the impact of technology adoption on rice production. Our study takes this approach a step further by investigating the impact of SWC adoption on conditional yield. In addition, we decompose estimated yield differences into components that can be interpreted economically. To address these questions we consider the performance of plots with and without SWC, carefully addressing plot and household heterogeneity among other factors. Our study differs from the previous literature in two respects. First, the nature of the data, multiple plots per household allows us to control for unobserved household heterogeneity that may impact adoption and production decisions. The data are particularly well suited to such an analysis as they reveal the SWC status of each plot owned by the household. Second, the data pertain to a period when there was no direct donor or government support of SWC in the country.[1] More importantly, the adoption was driven and achieved by farmers without hand-out incentives. The lessons learnt may have wider applicability not only in Kenya but also in other countries facing comparable problems of land degradation. However, one limitation that our study shares with other studies is the lack of longitudinal data. Plot level longitudinal data offer detailed information that overcomes difficulties inherent in a single cross section.

The rest of the paper is organised as follows. Section 2 presents the nature of the evaluation problem and a description of the analytical framework including the hypotheses to be tested. Section 3 motivates the estimation methodology and introduces the data and variable definitions. Section 4 presents the results of the data analysis (including salient yield and input differences between plots with and without SWC),

[1] In the mid 1990s donor support was withheld due to mismanagement and governance problems. Faced with budgetary pressures on public expenditures the government reduced the number of extension agents.

econometric estimates and main findings. In the last section we conclude the paper and discuss the implications for policy.

2. Conceptual framework and hypotheses

In the literature there are several theoretical approaches of modelling farm technology adoption decisions (see Feder *et al*., 1985 for a survey). In this paper we see two important issues that we need to address in a model describing farmer behaviour. These issues have been addressed in previous studies, but only separately and not jointly. First, farmers' SWC adoption and production decisions may be simultaneous (Feder and Slade, 1984). This simultaneity may also be due to unobserved variables correlated with both adoption and production decisions. Second, households do not make adoption decisions randomly; instead they are based on expectations of how their choices affect future crop performance. Consequently, adopters and non-adopters may be systematically different. These differences may also manifest themselves in farm productivity and could be confounded with differences purely due to SWC adoption. The results would be biased if we did not address this self-selectivity problem (Greene, 2000).

Whether or not a household adopts SWC technology depends on the costs and benefits of each technology (Shiferaw and Holden, 2001). The assumption we make is that a household maximises utility when choosing technology. However, we do not observe its utility, but only its choice of technology. In the analysis we therefore apply a random utility model (McFadden, 1973). The utility of each alternative is in turn determined by a set of exogenous variables, *Z*, and an error term. The exogenous variables are both household variables and plot characteristics. Adoption is assumed to occur if the utility of the soil conservation alternative is higher than the utility of the other alternative, i.e. if $I^*_{hp} = I^{sc}_{hp} - I^{nsc}_{hp}$, or if $Z_{hp}\gamma + u_{hp} > 0$ (the indices *h* and *p* refer to household *h* and plot *p*). If the variable I_{hp} reflects the soil conservation adoption decision and equals 1 if there is a SWC structure by household h on plot p and otherwise equals zero. We can write:

$$I_{hp} = 1 \quad \text{if} \, (Z_{hp}\gamma + u_{hp}) > 0$$
$$= 0 \quad \text{if} \, (Z_{hp}\gamma + u_{hp}) \le 0 \, . \qquad (1)$$

Hence the adoption decision, Z_{hp} is a vector of the exogenous variables including land size, market characteristics, human capital and social characteristics (Feder, Just and Zilberman, 1985; Rogers, 1995); γ is a vector of parameters and u_{hp} is an error term. The error term includes measurement error and factors unobserved to the researcher but known to the household. The variable I_{hp} is a dichotomous choice variable, and can be consistently estimated using a limited dependent variable model such as binary probit (Maddala, 1983).

To examine the impact of SWC adoption on farm productivity, one has to estimate yield functions for plots with and without SWC as a simultaneous system. Since plots with and without SWC are mutually exclusive, they cannot be observed simultaneously on a particular plot. Adoption of SWC may affect and even alter input use patterns and decisions (Kaliba *et al.*, 2000). The households may also be both adopters and non-adopters if they have more than one plot. Therefore, we specify two separate yield functions for plots with and without SWC:

$$y_{hp1} = \mu_1 + X_{hp}\beta_1 + \eta_h + \varepsilon_{hp1} \, , \quad (if \quad I^*_{hp} > 0) \qquad (2a)$$

$$y_{hp0} = \mu_0 + X_{hp}\beta_0 + \eta_h + \varepsilon_{hp0} \, , \; (if \;\; I^*_{hp} \le 0) \, , \qquad (2b)$$

The variables y_{hp1} and y_{hp0} are continuous variables, representing the value of output per hectare if I_{hp} equals 1 or 0, respectively. X_{hp} is a vector of explanatory variables and β_1 and β_0 are vectors of unknown parameters. Finally, η_h is an unobserved household specific plot invariant effect and $(\varepsilon_{hp0}, \varepsilon_{hp1})$ are error terms.[2] This error structure allows control for unobserved effects such as farming ability and intra-household correlation due to unobserved cluster effects.

[2] Although random effects models are usually applied to cross sectional time series data, these methods also apply for a single cross section when we have multiple plot level observations within the household.

SWC can affect farm productivity positively in at least three ways. First, there could be an increase in farm yields per hectare through increased soil depth and water retention capacity, etc. Second, adoption of SWC may reduce input costs. For instance, increased soil fertility through accumulated soil organic matter could decrease the need to apply fertilisers. Third, the productivity of factor inputs may increase. However, there may be several other reasons for investment in soil conservation. To organise our empirical work we rely on the above arguments, which suggest the following hypotheses to be tested.

Some empirical studies suggest that the impact of SWC on agricultural productivity is positive (Byriringiro and Reardon, 1996) while others suggest it is negative (Place and Hazell, 1993). We therefore first have to test the hypothesis that SWC has a positive effect on agricultural productivity.

Second, the decision to invest in conservation may create differences in input demand (Pitt, 1983). Inputs in the agricultural system such as land, labour and fertiliser are explicit arguments in the yield functions. There may be differences in production costs between plots with and without SWC. For instance, one may expect that there are savings in fertiliser costs with the SWC practice through reduced run-off and nutrient loss. Yesuf (2004) found for example in Ethiopia that adoption of SWC led to a reduced use of fertilisers. The hypothesis to be tested is thus whether adoption of SWC actually leads to significant reductions in other input factors such as labour, fertilisers and manure.

Finally, a change in soil quality may also affect the productivity of the mentioned inputs (Kaliba *et al*., 2000). The hypothesis to be tested here is whether SWC actually increases the returns from land and other input factors.

While testing for these hypotheses, we need to be aware of the fact that there are effects of SWC other than on productivity. For example, there might be other intangible benefits such as scenic beauty and even social status associated with conservation (Swinton and Gebremedhin, 2003). The latter suggests that preferences and behaviours of other community members affect individual farmer behaviour, in particular if there are social norms regarding who is a good farmer. Any deviations from this norm may entail private costs such as low self-esteem or low prestige, making over-investment plausible.

We also need to take into consideration that farm specific attributes such as land quality and slope may influence adoption decisions and costs. Many farmers with fragile and hilly slopes may be preoccupied with SWC to avoid future crop yield losses, suggesting that adoption benefits cannot be solely assessed in terms of current crop yields.

We will thus estimate yield functions to investigate the impact of soil conservation practices on yield and factor returns (Antle, 1983; Antle and Capalbo, 1993). This approach accounts for the fact that yield depends on inputs used in production and current or past soil conservation activities. Empirical studies of agricultural productivity have used a variety of estimation strategies. Some argue that direct estimations of production functions are likely to give biased parameter estimates because input use may be endogenous to production decisions (Berndt, 1991). As the season progresses, farmers may adjust input amounts depending on weather, availability of credit or pest conditions. As an alternative, estimation of the dual form of the production, i.e., a cost or profit function, has been suggested. However, this is difficult in the absence of good estimates of factor prices for labour and land. Moreover, the endogeneity problems of using the primal are specific to the plot, but since we control for plot specific characteristics they are likely to be modest. These effects are certainly bound to exist and must be kept in mind when interpreting results. Furthermore, a direct estimation of production functions is justified if farmers maximise expected yield value instead of actual yield value, as discussed in Zellner *et al.*, (1966). They argued that when the random disturbance term represents factors such as weather, and input quantities are chosen before the realisation of this disturbance, then estimates are consistent because input quantities are independent of the error term. Coelli (1995) argued that these conditions are typical of agriculture, and thus we adopt the primal approach in this study.

In this study we attempt to estimate yield functions with a flexible quadratic form, a so-called translog production function. Second order terms include squares of each input and interactions of inputs and productivity shifters (e.g. fertiliser and SWC investment, plot characteristics etc.). However, due to excessive multicollinearity, interaction terms needed to be dropped. What remains therefore is a reduced form translog function. Our methodology is similar to that of Byiringiro and Reardon (1996), Holden *et al*. (2001) and Adegbidi *et al*. (2004), but still differs in some important respects. First, instead of using dummy variables to represent soil conservation investment, we use area shares to measure the intensity of use. Thus, we do not assume that SWC only has an intercept shift in productivity. Second, we estimate productivity for two regimes, which avoids loss of information entailed in correcting for non-adoption alone. A t-test is used to test for significance of differences in input use intensities between the two regimes.[3] Finally, yields under the major SWC technologies are estimated separately.

3. Estimation

Estimation of the separate production functions (2a) and (2b) with selected samples is accomplished with an endogenous switching regression model (Lee, 1978; Maddala, 1983). To account for household heterogeneity over plots, we use a random effects model (Wooldridge, 2002). Sample selectivity is treated as a missing variable problem accounted for by including selectivity correction regressors in Eqns. (2a) and (2b). This makes the coefficient estimates of yield obtained from the two-stage procedure consistent (Maddala, 1983). The correction instruments are derived from the first stage probit model, which provides estimates of γ used to estimate the correction terms as follows:

$$E(\varepsilon_{hp1} \mid X_{hp}, I_{hp}^{*} > 0) = \sigma_{u1} \frac{\phi(Z_{hp}^{'}\gamma)}{\Phi(Z_{hp}^{'}\gamma)}, \qquad (3a)$$

and similarly for ε_{h0},

$$E(\varepsilon_{hp0} \mid X_{hp}, I_{hp}^{*} \leq 0) = \sigma_{u0} \frac{-\phi(Z_{hp}^{'}\gamma)}{1-\Phi(Z_{hp}^{'}\gamma)}, \qquad (3b)$$

[3] The test statistic is calculated as: $t = (X_{ip}^{sc} - X_{ip}^{nsc}) / \sqrt{Var(X_{ip}^{sc}) + (X_{ip}^{nsc}) - 2\,\text{cov}(X_{ip}^{sc}, X_{ip}^{nsc})}$.

where ϕ and Φ are the density function and the distribution function of the standard normal evaluated at $Z'\gamma$. The conditional expected yields are computed as:

$$E(y_{hp1} \mid X_{hp}, I_{hp}^{*} > 0) = \mu_1 + X_{hp}^{'}\beta_1 + \sigma_{u1}\frac{\phi(Z'\gamma)}{\Phi(Z'\gamma)}, \qquad (4a)$$

$$E(y_{hp0} \mid X_{hp}, I_{hp}^{*} \leq 0) = \mu_0 + X_{hp}^{'}\beta_0 - \sigma_{u0}\frac{\phi(Z'\gamma)}{1-\Phi(Z'\gamma)}. \qquad (4b)$$

The coefficients σ_{u1} and σ_{u0} represent the estimates of the covariances. If these covariances are nonzero, then estimates of equation (4a) and (4b) would be biased due to sample selectivity. The signs of the covariance terms σ_{u1} and σ_{u0} have an intuitive economic interpretation. If $\sigma_{u1} > 0$ and $\sigma_{u0} < 0$, then unmeasured returns are positively correlated with unobservable plot characteristics that are valued in the adoption of SWC. In that case, as the selection hypothesis proposes, plots of high return capabilities are selected for adoption. The reverse case, $\sigma_{u1} < 0$ and $\sigma_{u0} > 0$, casts doubt on the relevance of the selection hypothesis.

The two-step method does not guarantee correct standard errors for the coefficients because the imputed unobservable variables used in the second step are generated regressors rather than the true value. A common problem is that the standard error in the two step model is smaller than the corrected values, because the corrected variance-covariance matrix of the coefficients has an additional positive definite matrix from the first-step procedure. If the standard errors are not corrected, then hypotheses testing may be incorrect. Murphy and Topel (1985) offer a simple formula to correct the covariance matrix of the estimates. We use the correction factor to correct the standard errors in the second step, to generate the correct t-statistics, (Greene, 2000).

3.1 Data and variable description

The data come from a sample of Kenyan households from the Kiambu, Meru and Machakos districts. These districts, having contrasting SWC regimes even in the same household, make them suitable for a comparison of productivity performance. The data pertain to the 2001/2002 farming season, and cover the household socio-economic characteristics crops, yields and SWC status at the plot level. The households were interviewed two months after the maize harvest for optimal input use recall on the recent crop.

Table 1 gives the summary statistics for the model variables. There are two dependent variables. A separate model for SWC adoption is included. We include some variables related to the SWC adoption decision. *Conserve* is a binary dummy variable indicating whether there is an SWC structure on the plot or not. Next we consider some of the variables used in this estimation. The human capital of the household is indicated by the years of education of adult males and females in the household and age of household head. On average, household heads were 52 years of age, suggesting that farming households tend to be late in their life cycle. The dependency ratio was derived as the number of dependants (aged below 15 and above 65) divided by the number of aged between 15-65 years. Scarcity of land is given by the per capita land available which is land size weighted by the household size. The average per capita land under maize was 0.26 hectares, a finding consistent with official publications. The physical capital of each household is indicated by the value of livestock and availability of off farm income. On average, 62 % of the households had access to off farm income.

Output is the aggregated value of maize (*Zea mays*) and beans (*Phaselous vulgaris*) produced per hectare. We depart from the tradition of using a single crop yield for two reasons. First, maize and beans are both staple foods in Kenya and make up the dominant crop mix for small and medium farms. Second, the crops cannot be viewed separately since they are grown simultaneously on the same plot and there is the added advantage of minimized recall errors for such a dominant crop mix. The decision to aggregate over the two crops forces us to work with values, because quantities cannot be aggregated directly.

Table 1: Descriptive Statistics

Dependent variables	Units	Mean	Std.dev	Min	Max
Conserve	Dummy	0.86	0.33	0	1
Output value per hectare	Shillings	7590	24595	1400	42000
Soil and water conservation technology					
Bench area share	Share	0.046	0.081	0	0.68
Bund area share	Share	0.014	0.049	0	0.40
Ridge area share	Share	0.026	0.085	0	0.80
Inputs					
Family labour	Days/Hectare	61	71	0	180
Hired labour use dummy	Dummy	0.43	0.50	0	1
Hired labour	Days/Hectare	1.3	1.5	0	6
SWC maintenance labour	Days/Hectare	9.4	15	0	12
Fertiliser use dummy	Dummy	0.32	0.47	0	1
Amount of Fertiliser	Kg/Hectare	30	67	0	600
Manure use dummy	Dummy	0.30	0.57	0	1
Amount of Manure	Kg/Hectare	1040	1980	0	8000
Plot characteristics					
Plot area	Hectares	0.36	0.46	0.1	6.83
Slope					
Light slope	Dummy	0.34	0.47	0	1
Medium slope	Dummy	0.40	0.49	0	1
Steep slope	Dummy	0.24	0.42	0	1
Erosion status					
Lowly eroded	Dummy	0.06	0.13	0	1
Moderately eroded	Dummy	0.15	0.36	0	1
Highly eroded	Dummy	0.18	0.38	0	1
Soil depth					
Shallow (<25 cm)	Dummy	0.12	0.33	0	1
Moderate (25-50cm)	Dummy	0.54	0.49	0	1
Deep (>50cm)	Dummy	0.34	0.47	0	1
Household factors					
Average education	Years	7.0	2.6	1	21.75
Value of livestock	Shillings	45200	51250	28800	118600
Farm size	Hectares	1.43	1.24	0.5	8.3
Per capita land	Share	0.26	0.29	0.01	0.77
Prior Adoption	Proportion	0.68	0.81	0	1
Age of household head	Years	52	13.2	23	72
Dependency ratio	Share	0.32	0.19	0.01	0.8
Off farm income	Dummy	0.62	0.54	0	1
Perennial crops income	Shillings	1249	2688	640	6428
Share transport cost to sell price	Share	0.27	0.23	0.014	0.98
Distance to Market	Minutes	41	30	2	119
Social Capital					
Associations	Index	3.02	1.27	0	16
Trust	Index	4.36	1.03	2	18
Community attachment	Index	0.99	0.37	0	1.4
Information	Index	3.11	1.06	-4	13.6

There are a number of soil conservation measures used by farmers in our study. In the literature the practice is to choose one or two specific soil conservation measures as an indicator of investment (see Kazianga and Masters, 2001). The ratio of adopted practices to total number of conservation measures available has also been used to define the soil conservation variable for each farmer (Nowak, 1987), which is simple but ignores intensity of use. This study uses the share of land covered by each measure as the intensity of SWC measure on a plot; that is, the proportion of plot area devoted to the measure. On each plot there was a predominant SWC structure whose measurements are used in this analysis. The structures include benches and *fanya juu* terraces, both referred to as Benches. The other measure comprises of contour earth or stone bunds for soil erosion control or water harvesting, conveniently called Bunds. In many places farmers stabilised the bunds with Napier grass, which was also used as animal fodder. The last category is Ridges, which also includes micro basins, known as pits. The decision to group them together is based on the amount of labour time needed to construct them. Consistent with other studies of soil conservation in Kenya (Oosterndorp and Zaal, 2002), our data suggest that the average intensity of use of Benches is the highest with five percent of the area, followed by Ridges and Bunds with three and one percent, respectively.

With respect to inputs, labour is measured as the total amount of full labour days used for land preparation, seedbed preparation, planting, weeding, fertiliser and manure application and harvesting. Family and hired labour are separated in conformity with the other studies that found differences in their respective productivity. We note that the average number of days of family labour is higher than the average number of days of hired labour. This could result from careful timing of the use of hired labour. Family labour is applied throughout the year, while hired labour is typically employed during peak labour demand periods such as planting and harvesting. The average per hectare family labour used is 60 days with a maximum of 180 days. While there are disagreements over labour demands associated with SWC, most observers seem to agree that SWC increases labour demand in construction and maintenance. On average, households with SWC spent 9 days per hectare annually on maintenance.

Fertiliser and manure use average 29 and 1,000 kilograms per hectare, respectively. Although these amounts are far below those recommended for maize and beans, they are consistent with other findings from Kenya (Omamo *et al*., 2002). Because there are zero values for some households it is not possible to use a simple logarithmic transformation for these variables. Following Battese (1997) we included a dummy variable for positive amounts, to allow for an intercept shift for households with zero values for some inputs, as well as the logarithm of inputs for households with positive input levels. The log transformations reduced problems with non-linearity and outliers, improving robustness of the regression results (Mukherjee *et al*., 1998).

Plot specific attributes such as land quality and slope may influence both adoption decision and productivity. Arguably, many farmers with fragile and hilly slopes may be preoccupied with SWC to avoid future crop yield losses. It is therefore important to control for the impact of plot characteristics on yield. However, measuring such soil quality characteristics is both complicated and costly. Consequently, we resort to using approximate indicators such as slope, erosion status and soil depth.

The benefits of SWC depend on how much value the farmer realises from the sale of produce. The cost of transportation relative to local market price is a coarse measure of the degree to which prices must be forgone in order to sell the output in local markets. High transport cost reduces the returns to crops production and is therefore expected to negatively affect the value of yield.

High value perennial tree crops (coffee, tea) may contribute to agricultural productivity in various respects. On one hand, poor farmers in rural areas are unable to purchase productivity enhancing inputs like fertilisers due to capital and credit constraints, but incomes from such crops present an avenue for reducing such constraints. In addition, these cash crops have institutional input/output marketing arrangements that may benefit farmers (Jayne *et al*., 2004). On the other hand, there are concerns that cash crops compete with staples for labour and scarce land, jeopardising the ability of households to feed themselves in the event of market failure. We included share of revenue from tree crops per land holding to investigate its impact on the value of maize and beans.

Finally, we include indicators of social capital to explain the adoption of SWC. Many arguments have been advanced in the literature as to why social capital may improve adoption of social capital. Some of these include solving of collective action problems, reducing monitoring problems, development of revolving credit schemes to overcome incomplete, or non-existent capital markets and information flows. Revolving credit schemes involve all members contributing an agreed sum of money each period to the fund. They money can then be borrowed by one member each period if required, for financing SWC or buying equipment. The success of such schemes requires that members do not free ride which in turn demands trust. Networks and memberships of groups may also help overcome the impediments of information flows due to social divergence. In Chapter 2 we constructed the indices of social capital used here and also analyse their relationship to soil conservation. These are constructed from variables such as membership in organisations, degree of involvement, and participation in water projects, soil erosion control etc.

4. Results

4.1 Use of soil and water conservation, yields and inputs

One of our hypotheses was to test whether there are significant differences in input use between plots with and without SWC, with the expectation that SWC adoption would lead to savings of other inputs. Table 2 reports results for the mean differences in value of yield and input amounts for plots with and without SWC investments, using the t-test to test the null hypothesis of equality of means.

Table 2: Comparison of yield value and inputs for plots with and without SWC

Dependent variable	With SWC		Without SWC		Difference	
	Mean	Std dev	Mean	Std dev	With-Without	P value
Value of crop yield	8670	2,234	11320	6,506	-2,650	0.002
Inputs						
Family labour (Days/ha)	56	66	65	85	8.6	0.334
Hired labour (Days/ha)	4.2	3.7	4.6	2.98	-0.42	0.046
Amount of Fertiliser (Kilograms)	41	115	36	73	5.1	0.718
Amount of Manure (Kilograms)	1030	2474	870	1222	163	0.011

As can be seen in Table 2, the results are very mixed. Starting with input use we do not find clear differences with respect to family labour and fertiliser inputs. It is only in the case of hired labour that we find the expected significant input reduction with SWC. For manure we even find a significantly higher use on plots with SWC compared to those without. Soil fertility is partly an endogenous variable; hence large amounts of manure application might suggest that farmers apply more manure to plots with depleted soils. This may lend credence to the observation that SWC is used on eroded land, which may suggest that plots with SWC have low fertility and hence require more nutrient augmentation from manure. In line with previous studies (Pagiola, 1994), there are significant differences in mean value of crop yield for plots without SWC investments in comparison with plots with SWC. Plots with SWC have a significantly lower mean value of crop yield. This will be further analysed in the multivariate analysis. A notable feature is the higher variability in yield for plots without SWC in terms of standard deviation. This observation hints at the plausibility of SWC investments reducing variability in yields.

Many expect a direct positive relationship between SWC and yield. However, when a difference in yield between plots with and without soil conservation is observed, it is not straightforward to know the underlying reason for the difference. On the one hand, it is plausible that more productive plots attract SWC investment to retain or further augment the productivity. On the other hand, SWC investments may be adopted on eroded land in order to restore productivity that may have been lost due to erosion. A reason for this ambiguity could therefore be that there are differences in plots characteristics between plots with and without SWC investments. We use the Mann-Whitney test (a non-parametric version of the independent t-test) to test whether there are significant differences with respect to plot characteristics for plots with and without SWC for each of the categories. Table 3 presents the results.

Table 3: Differences in plot characteristics between with and without SWC

	Slope	**Erosion Status**	**Soil Depth**
	H0: $Slope^1=Slope^0$	H0: $Erosion^1=Erosion^0$	H0: $S\text{-}Depth^1=S\text{-}Depth^0$
Z	4.60	6.00	-1.324
P Value	0.000	0.000	0.2210

Superscripts 1 and 0 represent with and without SWC, respectively.

We report the overall differences for the plots. We reject the hypotheses of equal slopes between the plots with and without SWC. Plots with SWC measures seem to be, on average, more steeply sloping than other plots. As with erosion status, we find a statistically significant difference between plots with and without SWC, indicating that plots with SWC are more eroded than those without. Arguably, plots that suffer from high erosion, low water retention and low fertility would be strong candidates for SWC investments and according to Table 3, this appears to be the case. One may also argue that late SWC adoption may be a response to erosion rather than a preventive measure. Our comparisons thus far are pair-wise and do not control for other pertinent factors. Given the systematic differences identified in this descriptive section we will now turn to a multivariate analysis attempting to control for these differences in input intensities and plot characteristics while analysing yield values from plots with and without SWC.

4.2 Results of estimations

The estimation is conducted in two stages. The results of the probit estimates of Eqn. (1) are presented in Table 4. The fitted values of the probit model are used to construct the selectivity variables whether a plot has SWC or not, corresponding to Eqns. (3a) and (3b). The coefficients indicate the direction of likelihood of adoption of a given independent variable.

A more in-depth analysis of the adoption decision is given in Chapter 3. However, for the following analysis on the differences in productivity between plots with and without SWC, it is interesting to confirm, as indicated in the previous section, that increased erosion status and slope significantly increase the probability of adopting SWC. Also, the negative sign of the coefficient for soil depth supports the notion that farmers with deep soils are less likely to adopt SWC. The pattern of adoption is thus significantly affected by plot and soil characteristics, with what is typically considered to be worse plots being more likely to have SWC. This explains the findings by Shiferaw and Holden (1998) and Gebremedhin and Swinton (2003). In addition it gives further evidence of why one would not *a priori* expect higher productivity on land with SWC than on land without SWC.

This study confirms many of our expectations and previous adoption studies, for instance by pointing out the disincentive created by distance to market and the importance of social capital (for a discussion see Chapter3). As would be expected low tenure security, discourages long-term investments such as SWC. Although in some situations SWC investment may be a strategy to secure tenure on insecure land. Other variables like education and age of the head of household also have unexpected signs.

Land scarcity increases the likelihood of SWC adoption. The probability of using SWC is greater with higher population density as indicated by the per capita land ratio. This suggests that resource constraints promote the use of SWC farm technology, consistent with Boserup's (1965) theory. Access to information also appears to affect adoption of SWC. Households with access to more information were more likely to adopt SWC. These results suggest that improving access to information can help in the adoption of agricultural technology.

Table 4: Estimated probit results for SWC investment decision

Variable	Coefficient	P-value
Farm Characteristics		
Plot soil factors		
DEEP SOIL(>50 cm)	-0.128	0.074
HIGHLY ERODED	0.194	0.007
STEEP SLOPE	0.781	0.003
Perceived Tenure Security (reference HIGH)		
MEDIUM	0.252	0.326
LOW	-0.376	0.046
Geographic location (reference KIAMBU)		
MACHAKOS	0.544	0.148
MERU	0.357	0.397
Behavioural Characteristics		
Human capital		
EDUCATION	-0.160	0.0001
AGE HOUSEHOLD HEAD	0.081	0.098
AGE SQUARED	-0.006	0.208
Socio-economic		
DEPENDENCY RATIO	0.247	0.642
HIRED WORKERS	0.921	0.047
OFF FARM INCOME	-0.211	0.246
PER CAPITA LAND	0.734	0.093
PERENNIAL TREE CROPS	-0.66	0.025
DISTANCE TO MARKET	-0.003	0.081
PRIOR ADOPTION	0.083	0.373
Social capital		
ASSOCIATIONS	0.121	0.097
TRUST	0.146	0.055
COMMUNITY ATTACHMENT	-0.029	0.751
INFORMATION	0.212	0.011
Intercept	-1.973	0.199
Concordant predicted probabilities	84.21%	
Discordant predicted probabilities	15.79%	
Overall correctly classified	81.70%	
Sample size	388	
Pseudo R^2	0.201	
Log-Likelihood	-146.02	
Pearson Chi square (361)	587.08	(0.000)

Table 5 presents the coefficients of the regressions, with the selectivity correction, for SWC adopters and non adopters. Initially we included both quadratic and interaction terms in the yield functions. However, this specification contained inflated standard errors and led to insignificant parameter estimates with unexpected signs for some inputs. The lack of significance seems to be due to excessive multicollinearity. A likelihood ratio test also rejected the less restrictive specification ($p<0.732$). We therefore turned to a less flexible reduced form translog specification, which resulted in most coefficients being significant and signs consistent with economic theory. Moreover, dropping interaction terms also increased degrees of freedom. We conducted an F-test for the possibility of pooling the data from the two samples but this was decisively rejected ($p<0.01$).

The coefficients on selectivity correction factors from Eqn (3) and (4) provide some evidence that the selection model is necessary. For instance self-selection occurred in adoption of BENCH and RIDGE since the selection terms for the adopters are statistically significant at 1 and 5 per cent levels. These results suggest that if left uncorrected, self-selection would have biased the estimates of log value of yield equations associated with BENCH and RIDGE.

The results for plots with soil conservation investments are reported for BENCH, BUND, RIDGE and the POOLED sample. In the analysis of the results we will utilize this disaggregation and focus on the differences in coefficients between the various regimes. These variations represent of course the respective contributions of the explanatory variables to agricultural yield in the different regimes. They can thus help shed some light on our two hypotheses that SWC increases the agricultural yield and positively affects the productivity of other inputs.

We start with a comparison of the coefficients of the NONE and POOLED samples. In the POOLED estimation we have included the area shares of benches, bunds and ridges. These variables would capture any independent impact of the respective SWC structures. Only the coefficient for Ridge area share has the expected positive and significant coefficient. Unlike *BENCHES* and *BUNDS*, *RIDGE* structures are constructed annually involving the removal of old structures and the construction of new ones. This process ensures that soil is churned and well aerated, unlike bunds and benches, which excavate unfertile subsoil. The ridges are built perpendicular to the slope so that rain water is led away safely without destroying crops.

Table 5: Log Value/ha Function Estimates: Random effects estimates for switching regression with and without SWC

Variable	NONE Coeff	BENCH Coeff	BUND Coeff	RIDGE Coeff	POOLED Coeff
Soil conservation					
Bench area share					-0.863*
Bund area share					0.478
Ridge area share					0.967***
SWC maintenance labour/ha.					0.051
Inputs					
Family labour/ha.	0.102***	0.024	0.101***	0.054	0.034***
Square of family labour/ha.	-0.641***	-0.292	-0.633***	-0.641	-0.242***
Hired Labour Use Dummy	0.784***	0.679***	0.103	0.448*	0.004
Hired labour/ha.	1.172***	0.613***	0.475***	0.642***	0.325***
Fertiliser Dummy	0.119	0.305	1.097**	-0.131	0.724***
Amount of Fertiliser/ha.	0.408***	0.209	0.791***	-0.165	0.319***
Square of Fertiliser/ha	-0.074	-0.008	-0.079**	0.031	0.004
Manure Dummy	0.698**	0.982***	0.974	2.723***	0.944***
Amount of Manure/ha.	0.074	0.167***	0.159	0.259***	0.125
Plot characteristics					
Erosion status					
Moderately eroded plot	-0.091	0.538*	0.283	0.723***	-0.191
Highly eroded plot	-0.108	0.047	-0.112	-0.233	-1.344**
Slope					
Medium slope	-0.699	0.051	-0.343	0.444*	0.117
Steep slope	-1.566**	0.398***	-0.487	0.183	0.019
Soil depth status of plot					
Soil Depth (25-50 cm)	0.213	0.107	0.431	-0.107	0.151
Soil Depth (>50 cm)	0.729	0.301	0.635	0.199	0.517*
Household factors					
Share value of tree crops/ha	0.972***	0.524***	0.605***	0.673***	0.654***
Off farm income	-0.011	-0.001	-0.086	-0.132	-0.133**
Market Distance	-0.012***	-0.002	-0.003	-0.004	-0.004***
Farm size (Hectares)	-0.132*	-0.096*	0.031	-0.023**	0.184
Value of Livestock owned	0.186**	0.019	0.063	0.022	0.035**
Plot area (in Hectares)	0.615***	0.223**	0.335*	0.143	0.747***
Selectivity correction	-1.358**	0.508***	-0.521	-0.746**	-0.786***
Intercept	10.031***	6.829***	7.537***	9.857***	6.395***
Rho	0.165	0.622	0.792	0.654	0.199
Regression Diagnostics					
R-square					
Within	0.47	0.66	0.72	0.76	0.46
Between	0.29	0.45	0.57	0.56	0.36
Overall	0.43	0.47	0.62	0.46	0.42
Wald Chi-Square	181(23)***	261(23)***	145(23)***	166(23)***	218(27)***
Number of plots	70	259	102	96	457

***, ** and * significant at the 1%, 5% and 10% levels.

As opposed to the *Ridge area share*, the impact of *Bench area share* on the log value of farm production is negative, although only significant at the 10% level. We find no statistically significant effect of *Bund area share* on farm productivity. The results from *BENCH* and *BUND* may partly be a reflection of the fact that these structures impose additional costs by occupying otherwise productive land, at least in the short term (Pagiola, 1994). Similar findings are reported in the literature (Shiferaw and Holden, 1998; Adegbidi *et al*., 2004). The types of studies quoted above do not deal with our concern, since they use data that combine all SWC structures. Our approach to analysing the impact of SWC structures on value of yield utilises data at the level of the individual SWC treatments.

Our second interest is the impact of SWC on the productivity of other inputs. In general, there are significant differences in determinants of log value of output across the SWC treatments.[4] *Family labour* has almost identical impact on the log value of yield for NONE and for BUNDS but was not found to have statistically significant impacts for BENCH and RIDGE. Similarly, households with higher *Fertiliser* application earn the highest log values of yield for only BUNDS and then for NONE while the coefficients are small and insignificant for BENCH and RIDGE. Households with more *Hired labour* earn higher log yield values for all SWC structures, but the impact is even larger for NONE. The returns from *Manure* application are positive and significant for NONE but higher for BENCH and RIDGE, controlling for other factors. The largest impact is for RIDGES which suggests that they are more suited to manure application. There is thus no clear cut picture emerging regarding the impact of SWC on the productivity of different input factors. The results suggest that the impact of inputs for SWC adoption may be context dependent. This suggests that efforts to promote SWC adoption should focus on understanding these contexts.

Since we have found that SWC is overrepresented on steep and eroded soils with lower productivity, it is important to control for such *plot characteristics*. These variables also give us an opportunity to analyse which technology is best suited for which land category. Ideally, this should be done by running separate production functions for the

[4] Various Chow tests were made to test the hypothesis that coefficients for pairs of treatments are the same. For all tests the hypothesis that the coefficients are the same were rejected.

most important land categories. Unfortunately, the data do not permit this. Still, the existing results indicate that BENCH and RIDGE, treatments may successfully increase the productivity on moderately eroded plots. Similarly, while steep slopes affect the log value of output negatively on plots without SWC, this is not the case if a BENCH treatment is applied on such steep slopes.

Turning to *Household factors* we find a number of other interesting results. First of all, high returns from *tree crops* consistently improve the log value of maize and beans production across the various regimes analysed. This could be capturing the effect of a reduced capital constraint. Alternatively, it could be the effect of more integration in the input and output markets including credit (Jayne *et al*., 2004). Thus, tree crops could provide a win-win situation in which the trees boost incomes and forest products such as fuelwood at the same time as they increase food production. Subsequently, there appears to be a case for profitable expansion of tree crops.

The effect of *Farm size* on log value of yield is negative and consistent with much of the literature on farm size productivity effects (Benjamin, 1995; Heltberg, 1998). This holds for plots without SWC and for BENCH and RIDGE treatments. On plots without SWC, one can think of more use of other inputs. Since we control for land quality, labour input and other factors, our result suggests that smaller farmers attain not only higher land productivity but also higher total factor productivity. As would be expected, *Plot area* has a positive and significant effect on crop value, both with and without SWC.

Distance to markets has a significantly negative impact on the log value of output, particularly for plots without SWC. However, combined with the result from the probit analysis that *market distance* decreases SWC adoption, it indicates the importance of improving market access for remote farmers.

4.3 Robustness checks

We investigated the robustness of our estimation results in two ways. We allowed for the possibility that the SWC investments could have a longer life span than previously assumed. We therefore included plots with soil conservation investments up to ten years old. Some would argue that experience should improve productivity through learning by doing effects. Furthermore, there are studies that have shown that crop yields on terraces less than ten years old are higher than those that are older (Figueiredo, 1986). We then introduced an age variable for the SWC structure and an interaction term between SWC structure and age. The age variable was not statistically significant for all the SWC structures. The null hypothesis that age interaction terms in the model are jointly equal to zero could not be rejected for all structures. The F-statistics for joint significance of the interaction terms for BENCH, BUND and RIDGE all had P-values greater than 0.7. We also tested whether there were district differences in the productivity of SWC measures. The P-values of the interaction terms between SWC measures and district dummies all indicated that these interactions were insignificant.

4.4 Productivity decompositions

Our results so far appear inconclusive with regards to the impact of various SWC structures on value of output. We have also seen that there are systematic differences in plot characteristics and input quantities between plots with and without SWC. Of interest is to see the effect of adoption on the value of output when consideration is given to use of inputs and plot characteristics with and without SWC. Specifically, it would be of interest to know what percentage of production is due to changed plot status. Answers to this question may be useful to formulate scenarios that contribute to a better understanding of the role of SWC in agricultural production.

We therefore conduct two simulations based on the following scenarios. The first involves exploring the differences between SWC adoption on the log value of output and what the same households would have earned if they were non adopters. This can be interpreted as the 'SWC effect' on the value of output of adopters. Using the estimated parameters $(\hat{\beta})$ of the yield function in Table 5 evaluated at their respective sample mean values, we decompose the differences in value of output. Let the subscripts 0 and 1 indicate non-adoption and adoption status, respectively.

By employing a decomposition technique suggested by Oaxaca (1973), the estimated coefficient and the means of the two groups can be used to calculate SWC adoption/non-adoption yield value differences. Mean log yield differences can be written as:

$$\overline{\ln Y_1} - \overline{\ln Y_0} = \sum \bar{X}_1 \hat{\beta}_1 - \sum \bar{X}_0 \hat{\beta}_0$$
$$= \sum (\bar{X}_1 \hat{\beta}_1 - \sum \bar{X}_1 \hat{\beta}_0) + \sum (\bar{X}_1 \hat{\beta}_0 - \sum \bar{X}_0 \beta_0) \quad (5)$$
$$= \sum \bar{X}_1 (\hat{\beta}_1 - \hat{\beta}_0) + \sum \hat{\beta}_0 (\bar{X}_1 - \bar{X}_0)$$

The first term is the difference between adopter yield value and what the same farmers would have earned if they were non adopters. This can be interpreted as the 'SWC' effect on the yield value of adopters. The second term indicates the endowment effect between adopters and non adopters or what non-adopters would have gained if they had the characteristics of adopters. Adoption of SWC may not change features such as slope, but may change plot attributes such as soil depth, soil organic matter and degree of erosion. These biophysical factors act in concert with other factors such as inputs to shape cropping outcomes through maintenance of water balances, control of run-off, (Turner and Brush 1987).

The estimated mean (log) value difference between adopters and non adopters varies between structures. In estimating the predicted differences we follow Lee (1978) and exclude the selectivity terms from the set of variables that predict $\overline{\ln Y_1}$ and $\overline{\ln Y_0}$. Results are reported in Table 6.

Table 6: Decomposition of impact of SWC adoption on log yield value

	SWC effect			Endowment effect		
	BENCH	BUND	RIDGE	BENCH	BUND	RIDGE
Estimated Difference	0.642	0.412	0.263	0.642	0.412	0.263
Inputs	-0.29	0.33	0.52	0.15	-0.14	0.14
Plot Characteristics	0.39	-0.48	-0.28	0.49	0.20	-0.23
Household Factors	0.33	0.18	-0.21	-0.13	-0.06	-0.06

We can attribute the value differences as those due to differences in input use amounts and those due to plot differences or quality. Lastly there are those due to household characteristics largely in terms labour endowments, cash income constraints etc. All these factors are evaluated at the sample mean variable input levels. By this method, we decompose the productivity differences between the SWC structures. Overall we note that the differences are positive and largest for BENCHES followed by BUNDS. The productivity effect of adoption of BENCHES is largest for plot characteristics, which may suggest their effectives in bringing steeply sloping land into cultivation. The productivity effect for BUNDS and RIDGES is negative (-0.48 and -0.28), which suggests that these structures may not be the most appropriate on degraded plots. However, with regard to input use, there is a positive effect for BUNDS and RIDGE (0.33 and 0.52), which suggests that adoption of these structures induces use of variable inputs. The observed and unobserved household effects are associated with positive yield gains for those adopting BENCHES and BUNDS (0.33 and 0.18). This is consistent with the broader technology adoption literature, which finds that adopters are better farmers overall (Feder, Just and Zilberman, 1985). Turning to the gains that non adopters forfeit, we find that the largest returns would be from plot factors for those adopting BENCHES (0.49) followed by BUNDS (0.20). With regard to inputs use there is an almost equal gain for adopters of BENCHES and RIDGES at 0.15 and 0.14 respectively. The estimated aggregate productivity effect of SWC adoption on household factors was negative, which may help explain limited uptake.

The results in this section go beyond the findings of previous studies in the evaluation of benefits of SWC under changing input, plot and household characteristics. We found that SWC adoption appears to be useful in changing the impact of plot attributes on yield, although the contribution to predicted yield value is rather small. A natural extension of this analysis would be to calculate the profits per hectare with and without various SWC techniques, similar to the approach of Gebremedhin *et al.* (1999). However, this would demand detailed price information regarding the various inputs.

5. Summary, conclusions and implications

This chapter outlines a methodology to estimate the impact of soil conservation adoption on crop yields. The method is general enough to be applicable to the adoption of any technology because it accounts for self-selection and simultaneity. The yield equation is theoretically consistent with a smallholders' production function.

Based on the expectation that SWC affects the welfare of adopting farmers through improvements in overall productivity, savings in inputs and synergies with other inputs, these were framed as hypotheses and subsequently tested. The initial descriptive analysis, using two-sample t-tests and a Mann-Whitney (non-parametric) test, showed that plots without SWC had significantly higher value of yield per hectare and more hired labour than plots with SWC. However, plots with SWC had significantly higher amounts of manure. The higher mean value of yield on plots without SWC was expected to result from a negative selection since it was found that plots with SWC had significantly steeper slopes and more erosion than the plots without SWC. This expectation was confirmed by the results of a probit that showed that SWC is positively correlated with steeper slopes, more erosion and less soil depth.

In order to further analyse the productivity implications of SWC, random effects switching regressions were estimated for each of the three identified SWC technologies. The results showed, among other things, significantly different impacts on yield from plot characteristics and inputs, depending on which technology was used. Benches seemed e.g. to improve the productivity on steep slopes and ridges on moderately eroded plots. Regarding inputs, Bunds seemed to increase the productivity of fertilisers while Ridges gave the highest return to manure.

The estimation results were then used in a decomposition analysis of how inputs, plot and household characteristics contribute to value of yield. We consider two scenarios. First, what the farmers would have earned if they were non-adopters. Second, what non-adopters would have earned if they had characteristics of adopters. The simulations indicated that the returns from plot characteristics increase with adoption. The return from other inputs given SWC was not as clear – possibly because of higher applications of inputs to compensate for the lack of SWC.

The evaluation of the hypotheses in this case study are thus less clear than expected, but does shed some light on the earlier inconclusive literature regarding the impact of SWC on agricultural productivity. One cannot expect higher overall productivity on plots with SWC since these structures are overrepresented on plots with steep slopes and erosion problems. The relevant evaluation is instead if such vulnerable and degraded plots have higher productivity with rather than without SWC. SWC can lead to savings in various factor inputs, but this is not a general finding and needs to be tested from case to case and input by input. SWC can lead to higher productivity of other inputs but the evidence is inconclusive and seems to depend on complex relationships among technologies, plot characteristics and inputs.

Methodologically, the paper has made some contributions. One contribution is pointing out the appropriateness of sample separation. Published literature has not analysed the relationship between SWC and land productivity, separating between adopters and non-adopters. This study even divided the adopters into three different SWC practices. Econometrically this was done by applying a two-stage random effects switching regression approach that handles the problems of self-selection and simultaneity. Finally, a simulation exercise was conducted to tease out the impact of adoption on some key areas of interest – plot characteristics and agricultural inputs.

Some of the results obtained here are supported by similar conclusions by Place and Hazell (1993) who did not find a significant impact of land investment on productivity. They observed that where investment fails to lead to greater productivity even if correlated to SWC, this may be because the purpose of investment is conservational rather than yield enhancing. In an analysis of Gambia, Hayes *et al*., (1997) found that some land investments enhanced yields, despite using a substantially different empirical strategy.

Other important positive determinants of farm productivity, besides traditional inputs, include plot size, livestock and value of tree crops while distance to market has a negative impact on the value of agricultural output. The empirical analysis indicated strong evidence confirming that in Kenya more tree crop income increases agricultural productivity. The estimates were consistently highly significant and in the various specifications. Agroforestry initiatives thus seem to have great potential in these areas. Plot size is positively correlated to value of output, which indicates economies of scale. Further fragmentisation of land in Kenya can therefore not be expected to raise per hectare output. Finally, efforts to improve market access (e.g. through construction of rural roads) could in the long-run have broad implications on adoption of SWC and profitability of agriculture.

A limitation of this study is the incomplete modelling of the substitution possibilities between SWC and other purchased inputs, particularly fertilisers. This limitation is not attributable to the methodology but is due to data limitations. As larger and possibly longitudinal data become available, the issue of substitutability and complementarities between SWC and other inputs may be addressed more thoroughly. Another natural extension of the simulation analysis, given availability of factor prices, would be to calculate the per hectare profit levels with and without various SWC measures.

This analysis has focused on private adoption decisions and potential private returns from such decisions. However, it should be remembered that these decisions are also important from a societal point of view since private decisions to conserve would also limit negative externalities with respect to downstream effects from erosion such as sedimentation and pollution of rivers. Future research should investigate societal benefits of SWC adoption, since they could be the basis for public decisions to increase the incentives for private conservation.

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