Social Capital and Technology Adoption on Small Farms: The Case of Banana Production Technology in Uganda.

by

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DECLARATION

I declare that the dissertation, which I hereby submit for the degree of Doctor of Philosophy in Agricultural Economics at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other University.

DEDICATION

To: Stephen, Davis, Daphine and my parents

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ABSTRACT

In recent years, development practitioners and policy makers have increasingly become interested in social capital as an additional instrument for economic development. However, within the applied economics literature on the adoption of agricultural technologies, research on the role of social capital in adoption decision-making is scant. Furthermore, there is a paucity of information regarding the determinants of social capital accumulation among rural households in developing economies. This study examines the nature of the relationship between social capital and crop management decisions of Ugandan banana farmers.

This dissertation develops a model of technology adoption that incorporates social capital and offers two explicit mechanisms through which social capital may influence technology adoption. A model of the agricultural household, which considers the effects of incomplete markets in farm production decisions, provided the theoretical framework for an econometric analysis to predict the choice and demand of improved banana management technology. The core theoretical framework was extended by explicitly incorporating social capital as a component of exogenous income and information accumulation processes.

Empirical analysis was based on the primary data collected in a survey of 400 banana-producing households in Uganda through face-to-face interviews with the primary production decision makers. The households were selected from the three major banana-producing regions of Uganda using multi-stage random sampling methods.

A combination of econometric methods was employed. A Probit model was used to estimate the probability of using an improved banana management practice and participation in an association. The extent of use of improved banana management practices was estimated by two methods, namely, ordinary least squares (OLS) and the Heckman procedure to account for sample selection in some equations. Intensity of participation in associations was estimated with a Poisson model. A negative binomial model that allows for over dispersion in the data was employed to identify the determinants of the intensity of participation in private social networks.

The results of the study indicate that different aspects of social capital shape the decision to use and the extent of use of an improved management practice, but the nature of effect is specific to the practice as well as the form of social capital. Participation in associations and the characteristics of those associations are important determinants of banana production management decisions. Participation in associations and private social networks is, in turn, influenced by household wealth, education, institutional environment, and social heterogeneity of the community. Aside from social capital, other factors that are significant in explaining variation in use of improved crop management practices among farmers have been identified. Market incentives and household factor endowments were the most important of these factors in decisions regarding use of improved banana management practices. The existence of separability between consumption and production decisions, a major analytical feature of the model of the agricultural household, also appears to be practice-specific, which suggests that production orientation is associated with the use of practices.

Key words: Social capital, technology adoption, Bananas, Uganda.

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ACRONYMS AND ABBREVIATIONS

BBW	Banana Bacterial Wilt
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
IFPRI	International Food Policy Research Institute
INIBAP	International Network for the Improvement of Banana and Plantain
Km	Kilometre
LC	Local Council
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MFEPD	Ministry of Finance, Economic Planning and Development
NARO	National Agricultural Research Organization
NGO	Non-governmental Organization
R&D	Research and Development
SD	Standard Deviation
SWC	Soil and Water Conservation
UBOS	Uganda Bureau of Statistics
Ugsh	Uganda Shilling

CHAPTER 1
INTRODUCTION

1.1. Background

In Uganda, agriculture is the most important economic activity, providing income, employment and foreign exchange. The sector contributes 43 per cent of the gross domestic product (GDP) and 85 per cent of national export earnings. It also provides most of the raw materials for Ugandan industries (Ministry of Agriculture, Animal Industry and Fisheries [MAAIF] and Ministry of Finance, Economic Planning and Development [MFEPD], 2000). The agricultural sector is dominated by food crop production, contributing 71 per cent of the agricultural GDP. Only one third of the food crop produced is marketed, implying that the agricultural economy is still oriented towards subsistence production (MAAIF and MFEPD, 2000).

Much of the agricultural output comes from about three million smallholder farmers, who constitute three-quarters of the total farming population, but a large proportion of these people live under conditions of poverty. About 48 per cent of the rural population lives below the poverty line and 25 per cent cannot even meet their daily food requirements (MAAIF and MFEPD, 2000). Given that about 85 per cent of the population live in rural areas and derive their livelihood primarily from agriculture, a strategy to develop agriculture as a stepping-stone for poverty reduction in rural areas is realistic.

Agricultural development is ranked high on the agenda for poverty alleviation in the country. High rates of inflation and political insecurity hampered growth in the agricultural sector during the 1970s and early 1980s. In 1987 the government launched an economic recovery programme based on decentralized decision-making. The aim of the decentralized policy was to introduce efficiency and effectiveness in the generation and management of resources and in the delivery of services (Decentralization Secretariat, 1994). Key policy constraints were removed, including the control of food and export crop marketing and pricing by the government and parastatal monopolies, which led to a shortage of foreign exchange.

As a result, the trends in the production and export of agricultural commodities have since been upwards. It is clear that the government's strategy regarding agriculture and poverty is based on continued growth in the share of farming production that is marketed (MAAIF and MFEPD, 2000).

While the country registered a considerable growth in the agricultural sector during the period 1992 to 2000 (UBOS, 2003a), there are still problems. For example, the recent national household survey conducted between 2002 and 2003 shows that there has been a reversal in the downward trend in rural poverty indicators over the past decade (Table 1). There may be a number of reasons behind this reversal in poverty reduction trends, but low agricultural productivity looms large amongst the possible explanations. As in many other Sub-Saharan African countries, agricultural productivity in Uganda has stagnated relative to population growth. After the economic liberalization in 1992, the positive growth registered in the agricultural sector during the period 1992 to 2000 was achieved through increases in the area under production rather than through a growth in agricultural productivity (MAAIF and MFEPD, 2000).

Table 1. "Head count" percentage of the Ugandan population living in households with a real private consumption per adult equivalent below the poverty line for their region

Region	1992	1997-98	1999-2000	2002-03
National Rural	59.7	48.7	37.4	41.7
Central	54.3	34.5	25.2	27.7
East	60.6	56.8	36.7	48.3
West	54.3	44.0	27.4	32.7
North	73.0	61.8	65.4	65.0

Source: UBOS (2003b)

Although there is still much scope for the expansion of acreage under cultivation in the country, land for agricultural development is becoming increasingly scarce in some areas. This is particularly true in the area around Lake Victoria, as well as in the highlands of the southwest and in the Eastern regions, where population densities are high and the average landholding is about 0.5 hectare (Gold et al., 1999), compared to the national average of 2.2 hectares (MAAIF and MFEPD, 2000). The highlands are the country's most fertile areas, but they are also more vulnerable to land degradation due to high population pressure and high altitude in some places, thus underscoring the importance of introducing land-saving technologies. Even those who attribute the positive supply response in the agricultural sector to liberalization are pessimistic regarding the scope for further supply increases. For example, Dijkstra and Van Donge (2001) argue that the supply response to liberalization could have run its course and that further growth in the agricultural sector will require investment.

Low productivity in the Ugandan agricultural sector is generally due to a number of direct and indirect factors. Direct factors include soil fertility decline and the increased incidence and intensity of pests and diseases. Indirect factors include: imperfections in both product and factor markets associated with high transaction costs, price risks and the use of low-yielding varieties or inputs (MAAIF and MFEPD, 2000). Furthermore, adoption rates are low for the agricultural technologies that have been developed to mitigate the negative effects of these constraints. The current adoption rate of new technologies in the agricultural sector is estimated at about 30 percent (MAAIF and MFEPD, 2000), thus underlining the need for a better understanding of the adoption process and constraints in order to guide policymakers in designing appropriate policies to stimulate adoption. Increased adoption of improved technologies in the agricultural sector is crucial for accelerating agricultural productivity and hence poverty alleviation in the country.

1.2. Statement of the research problem

Understanding the determinants of technology adoption has long preoccupied economists concerned with the crop productivity potential in developing economies (Feder et al., 1985; Feder and Umali, 1993). The effect of both the endogenous (i.e. human capital, attitudes towards risk and uncertainty or access to financial capital) factors and the exogenous factors (i.e. agro-ecological factors or market constraints) on the adoption process has been examined. However, most of the earlier adoption studies were conducted on the green revolution technologies (i.e. improved seed and complementary inputs such as fertilizers, pesticides and mechanization) that were basically high external input technologies, introduced into the communities from external sources. After the green revolution, other than the continued releases of high-yielding varieties, many of the crop management technologies recommended for small farmers in developing economies have entailed relatively low levels of external inputs. There are a number of reasons for the growing interest in these technologies, among which is their affordability to poor farmers and their environmentally non-degrading nature (Lee, 2005).

Low external input technologies for crop management have features that distinguish them from the green revolution technologies. Specifically, the improved banana production management technology disseminated to banana producers in Uganda differs from the green revolution technologies in two important ways. Instead of being introduced in tangible form as a physical package of seed and other complementary inputs such as fertilizer, the improved banana production management technology is disseminated in the form of knowledge and the physical technology is made on the farm, using primarily local resources. As such, the improved banana production management technology is not only knowledge-intensive but also demands more of the farmer's resources such as labour, land and skills. These factors may cause the pattern of adoption to differ from that of green revolution technologies.

Modelling efforts have been made in the past to explain time lags in the adoption and partial adoption of technologies. A major emphasis in the modelling of adoption behaviour was the role of risk and profitability. Information was identified as an important variable that interacts with the endogenous variables (risk preferences and skills) to influence adoption. Policies to promote the diffusion of technologies based on the results of previous research were biased towards top-down approaches, reflecting the supply-driven, commodity focus of national agricultural research systems and the international centres.

Although it was recognized that information is diffused from early adopters to non-adopters (Kislev and Shchori-Bachrach, 1973; Hiebert, 1974), factors that intervene in the information diffusion process remained largely unknown in the economics literature of technology adoption. In particular, the role of social capital in technology adoption, which may vary across locations or among farmers within the same location (Alesina and La Ferrara, 2000; Putnam, 1993), has received limited attention in the economics literature despite having long been recognized as an important factor in rural sociological work.

Recent attempts by economists to include sociological considerations in the adoption process have mainly stressed the possibility of late adopters copying or imitating early adopters to illustrate the problem of free riding on the investment in information made by early adopters. The basic assumption underlying the classical studies of social learning was that the information generated by early adopters was freely available to the whole village and differences in individual social learning were attributed to endogenous factors (i.e. prior beliefs, risk or human capital), with less consideration being given to the exogenous factors, such as social interaction (e.g. Kislev and Shchori-Bachrach, 1973; Hiebert, 1974; Feder and O'Mara, 1982; Feder and Slade, 1984; Foster and Rosenzweig, 1995).

As the more recent literature demonstrates, information diffusion may be a function of social capital (Conley and Udry, 2001; Collier, 1998), suggesting the possibility of differences in access to information from early adopters by potential adopters that may lead to differences in adoption rates. Social capital may influence social learning and technology adoption in a number of ways. First, social capital reduces the cost of information acquisition since it can be acquired passively during social interactions or actively from people who already know each other. Second, social capital reduces the uncertainty about the reliability of information. Information is likely to be given a higher value if it comes from trusted people. Third, social capital facilitates a willingness and cooperation in sharing information, thereby revealing tacit information that would be difficult to exchange otherwise (Yli Renko et al., 2002). Social capital also reduces transaction costs in a range of markets (such as output, labour and credit) that are endemic in most developing economies (Fafchamps and Minten, 2001).

Despite its potential, little has been done to estimate the effect of social capital on technology adoption in developing countries. In the few attempts that have been made, the emphasis has been on social learning (Isham, 2000).

The possibility that social capital may influence technology adoption through other mechanisms, such as access to bilateral transfers that relax expenditure constraints, has not been fully explored.

Finally, if social capital is important in adoption decisions, then policy makers should be interested in factors that influence its formation. However, studies that have examined the effect of social capital on technology adoption rarely go beyond its impact to analyse its determinants in rural areas. Yet, information on what influences social interaction in rural areas is important, given that the farmer-to-farmer model is increasingly being used as an alternative to the traditional extension model. The traditional extension model has recently been criticized for its failure to improve the productivity of low-input agriculture in developing economies (Carney, 1998; Rivera and Zijp, 2002). Uganda is pursuing a general policy of agricultural extension that diverges from the traditional extension approach in favour of farmer-to-farmer approaches (MAAIF and MFEPD, 2000). Hence information regarding the factors that influence social interaction in rural areas is of critical importance.

1.3. Objectives of the study

The general objective of this study is to examine the nature of the relationship between social capital and the use of improved banana management practices (i.e. mulching, manure application and sanitation) in Uganda.

Specific objectives are to:

a) conceptualise, define and measure social capital;
b) identify the determinants of social capital;
c) analyse the decision-making processes of banana farmers in the adoption of improved banana management technology; and
d) determine the effect of social capital and other factors on the use of improved banana production management practices (i.e. mulching, manure application and sanitation practices).

1.4. Hypotheses

Social capital in the form of social networks provides various services to individuals in developing economies. These services could link social capital to the choice and extent of use of a crop management technology through different mechanisms. Some of these mechanisms may be complementary while others are independent or offsetting. At least three services provided by social networks that may interact with a household's technology adoption decisions can be distinguished. These are: (1) a social learning environment; (2) bilateral transfers that may relax the household's credit or risk tolerance constraints; and (3) facilitation of collective action where coordination is needed due to technological externalities. Since no substantial technological externalities are involved in the adoption of banana production management practices, the present study focuses on the first two.

Social capital, social learning effects and technology adoption

In many developing economies, informal information dissemination mechanisms remain the only available source of information for many farmers. Farmers can passively or actively seek information from their neighbours or observe their neighbours' experiments (Foster and Rosenzweig, 1995; Collier, 1998) during social interactions. Since information may come in the form of an externality, social capital reduces the cost of information accumulation and enables farmers to adopt new farming practices. The following testable hypotheses can be derived.

Hypothesis 1: Households with a higher participation in social networks have better access to information and are more likely to use improved banana production management practices. Network effects can also come in the form of conformity pressure exerted on farmers to adopt by their peers who have adopted (Moser and Barrett, 2003). Conformity effects and social learning effects are not mutually exclusive, but may represent effects that complement and reinforce each other. Disentangling these effects would be a worthwhile exercise but limitations in the data available are a constraint on such estimation in the present study.

Hypothesis 2: Social networks with leaders who are better educated and of higher livelihood status than most members promote social learning and technology adoption. Because the wealthier and better-educated farmers are more likely to mobilize and exploit the strength of the weaker ties (Rogers, 1995; Granovetter, 1973; Broeck, 2004), they serve as a link between their social network members and the external sources of information.

Hypothesis 3: Social networks with participatory norms of decision making encourage cooperation among members that in turn facilitates information sharing and exchange and hence technology adoption.

Social capital, bilateral transfers and technology adoption

Social capital may facilitate bilateral transfers that could influence crop management decisions. As noted by Fafchamps and Lund (2003), social capital facilitates gift transfers and informal borrowing either because altruism must be nurtured by intimate personal contacts or because trust is required for the promise of reciprocity to be credible. Bilateral transfers may also work through different mechanisms that can be complementary or contradictory. Second, access to a social network that can help in times of crisis may reduce risk-aversion (Fafchamps and Lund, 2003) and enable the individual to experiment with new technologies. When markets are distorted, better access to assistance, whether in kind or informal credit, complements the households' family resources, which may increase economic freedom while making production decisions. Based on this discussion, the following hypothesis can be derived:

Hypothesis 4: Social capital promotes access to bilateral transfers, which in turn increases economic flexibility and willingness to use improved banana management practices. However, if the primary purpose of bilateral transfers is to smoothen consumption after a shock, it is likely that such transfers will be used for immediate consumption rather than investment (Fafchamp and Lund, 2003), and the effect could be ambiguous.

Social capital is one of the possible factors that influence adoption decisions. The hypothesized effects of other factors that are likely to influence the use of improved banana production management practices are discussed in Chapter 7.

Determinants of social capital

Social capital is not uniformly distributed across locations (Putnam, 1993; Knack and Keefer, 1997). Some communities have more social capital than others, even within the same location, and some households have more social capital than others. The heterogeneity in the distribution of social capital among rural households may originate from two sources: differences in investment in social interactions, as well as differences in the endowments of social capital in the communities where they live (Alesina and La Ferrara, 2000; La Ferrara, 2002). The following hypothesis is derived:

Hypothesis 5: There is a positive relationship between the ownership of other types of capital (such as physical and human capital) and investment in social capital.

1.5. Organization of the dissertation

The next chapter provides a brief overview of banana production and its economic importance in Uganda and describes the characteristics of the crop management technology. Recommended production technologies are described with special mention of relevant production constraints targeted by the improved technology. The intention is to highlight the practical problems of banana production and link them with the conceptual approach of this dissertation.

Chapter 3 presents a review of the theoretical and empirical literature on the adoption and diffusion of crop innovations, differentiating seed-based innovations from those related to mulching, manure application and crop sanitation for a perennial crop. The role of information and economic constraints in explaining adoption behaviour is discussed and empirical factors that influence access to information are reviewed. The chapter also highlights the key features of an agricultural household model.

Chapter 4 presents the general overview of the literature on social capital, focusing on its meaning, forms and determinants. Drawing from this literature, a definition of social capital used in the present study is presented. Important mechanisms through which social capital may influence the adoption of technologies such as those studied in this dissertation are identified.

Chapter 5 presents the conceptual framework for analysing the adoption decision-making processes of banana farmers regarding technology adoption and a model of technology choice. In the model social capital is incorporated as a component of exogenous income and the process of accumulating information.

Chapter 6 describes the data sources and sample characteristics. The chapter presents a summary of the methods used for the sample domain stratification and provides an overview of the domain, as well as the stratifying criteria and procedures used for data collection. A summary of the survey instruments is also presented.

Chapter 7 establishes the link between the empirical estimation and theoretical analysis developed in Chapter 5. The econometric models used to test the hypotheses are described. The chapter also defines the variables used in the empirical estimation. Some of the methodological issues inherent in using cross-sectional data to analyse technology adoption are discussed and reduced-form models for household participation in associations and private networks in rural areas of Uganda are presented.

Chapter 8 presents the descriptive statistics on the use of improved management practices and social capital. The rates and extent of adoption are compared using elevation, exposure, market access and farm holding as the stratifying variables. Descriptions of the local social structures, participation in associations, associational characteristics and household private social networks are compared across regions and infrastructure development.

Chapter 9 presents and discusses the results of the impact of social capital and other factors that significantly affect the adoption of the practices of mulching, manure application and sanitation in banana production. The empirical results of the factors that influence the household's decision to participate in local associations and private social networks are also presented and discussed in this chapter.

Finally, Chapter 10 presents a summary of the key findings from the research conclusions and outlines the implications for policy. Suggestions for further research are also presented.

CHAPTER 2

BANANA PRODUCTION AND ITS ECONOMIC IMPORTANCE IN UGANDA

This chapter provides a brief description of key features of banana production in Uganda and highlights the physical, market and social conditions under which the crop is produced. The economic importance of the banana crop is summarized. An overview of the banana production constraints, recommended crop management technologies and sources of information are presented.

2.1 The economic importance of bananas

Bananas are a major food staple of the country as well as a cash crop. The crop provides an estimated 30 per cent of the calories, ten per cent of the protein and five per cent of the fat intake of the population, representing 25 per cent of the total value of agricultural output (Kalyebara, 2002). The per capita annual consumption of bananas in Uganda is the highest in the world at approximately 0.70 kg per person per day (International Network for the Improvement of Banana and Plantain [INIBAP], 2000; National Agricultural Research Organization [NARO], 2001). Compared to other important crops in the country, banana occupies the biggest proportion of utilized agricultural land (about 1.4 million hectares or 38 per cent of the total utilized land), making it the most widely grown crop (Figure 1) and serves as one of the most important food security crops for central, western and eastern Uganda (NARO, 2001).

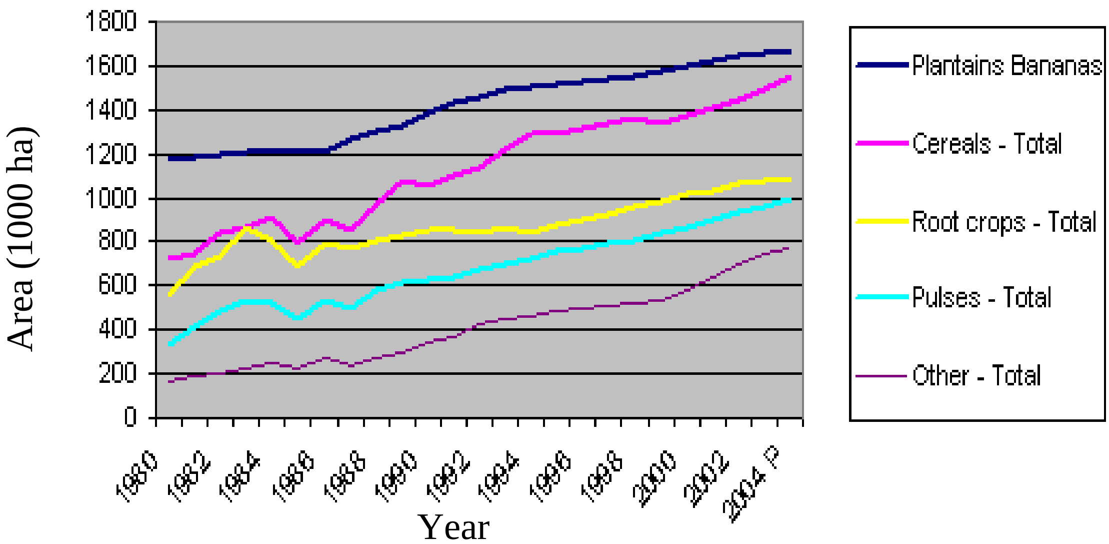

Figure 1. Area planted to major food crops in Uganda (1000 hectares) (MAAIF, 2004)

Uganda is the second largest producer of bananas in the world. In 2001, the annual output was estimated at 10.5 million metric tons, accounting for over 10 per cent of world output (FAO, 2001). However, the country is among the smallest exporters of bananas in the world. Most of its production is consumed nationally, with some regional trade and very small quantities exported to Europe. About 90 per cent of Uganda's banana output is marketed domestically (Mugisha and Ngambeki, 1994).

Although the export potential for bananas produced in Uganda appears to be limited (Tushemereirwe et al., 2003), the future prospects for local banana markets appear to be good. A major factor is the urban population boom, which has driven prices upward in the food markets of Kampala, the country's capital city, and other cities. The main constraint limiting the profitability of banana marketing stems from the high cost of transportation from major suppliers who are over 300 kilometres away from the major market (Kampala), and the risks involved. Transport costs account for 80 per cent of total marketing costs (NARO, 2005).

In Uganda, bananas can be used in many ways and forms. Bananas are eaten in both urban and rural areas as cooked food, juice or beer, as roasted or sweet snacks, or as dessert. The cooked food and juice also have cultural functions in some stages of the wedding and funeral rites. The different parts of the crop have different uses in the daily life of a farm household. The leaves are used in the steaming of food, sheaths are used to make ropes and crafts, and pseudo-stems provide fodder. The multiple uses of bananas in Uganda are derived from the country's great crop diversity. Uganda is the second greatest centre of banana diversity after East Asia (Edmeades et al., 2005).

In addition to their common use, banana varieties grown in Uganda are differentiated by the differences in their genome groups and observable characteristics. Edmeades et al. (2005) classify the bananas grown in Uganda as either endemic (or consistently present) in East Africa or non-endemic. The endemic banana varieties, including the AAA-EA genome group, consist of two use-determined types (i.e. cooking bananas [*matooke*] and beer bananas [*mbidde*]) and account for about 85 per cent of all bananas grown in Uganda (NARO, 2001). The non-endemic bananas grown in Uganda are locally adapted, introduced banana varieties, which have their origins in South-East Asia, and a number of conventionally bred hybrids originating from the Honduras (Edmeades et al., 2005). Among the locally adapted, introduced varieties are exotic beer and sweet bananas (AB, ABB and AAA genome groups) and roasting bananas or plantains (AAB genome group).

According to Edmeades et al., (2005), the exact number of banana varieties in East Africa is still a subject of on-going debate among breeders. The East African highland bananas are locally identified by their local names, which vary from one location to another. The same name may be given to the same clone or a single clone may have different names in different parts of the country. Karamura and Karamura (1994) identified a total of 233 East African highland banana varieties (genome group AAA-EA), of which 145 are cooking bananas and 88 are beer bananas.

2.2. Banana production

The exact period when the banana crop was first introduced to Uganda is not known, but there are speculations that the crop may be as old as agriculture itself (McMaster, 1962). Since its introduction to the country, banana cultivation has steadily expanded in both acreage and popularity. For example, in 1958 the crop occupied a total area of about 485 800 hectares and supplied the main subsistence to 35 per cent of the total population (McMaster, 1962). In 2000, it was estimated that bananas occupied about 1 510 000 hectares of land (MAAIF and MFEPD, 2000), representing about 60 per cent expansion in about 40 years. At present, the crop is grown in almost every part of the country, though at varying intensities (Figure 2). Clearly visible patterns of banana growing can be observed from the south up and along the central part of Uganda (known as “the banana belt”).

Production is concentrated at altitudes between 900 and 1 800 metres above sea level (Davies, 1995). Permanent cultivation requires a minimum annual rainfall of 1 000 millimetres, which is distributed evenly throughout the year. A bimodal rainfall characterizes Uganda, with peaks recorded during the months of April to May and October the November, making the country particularly suitable for banana growing.

An estimated 61 per cent of the national banana crop is produced in the western region of the country, 30 per cent is produced in the central region and the remainder in the eastern region (UBOS, 2002) and other parts. Most banana production takes place on small subsistence farms of less than 0.5 ha (Gold et al., 1998). The crop is mainly grown for home consumption and a contribution of 8 to 22 percent of rural revenue is realized (Ssennyonga et al., 1999).

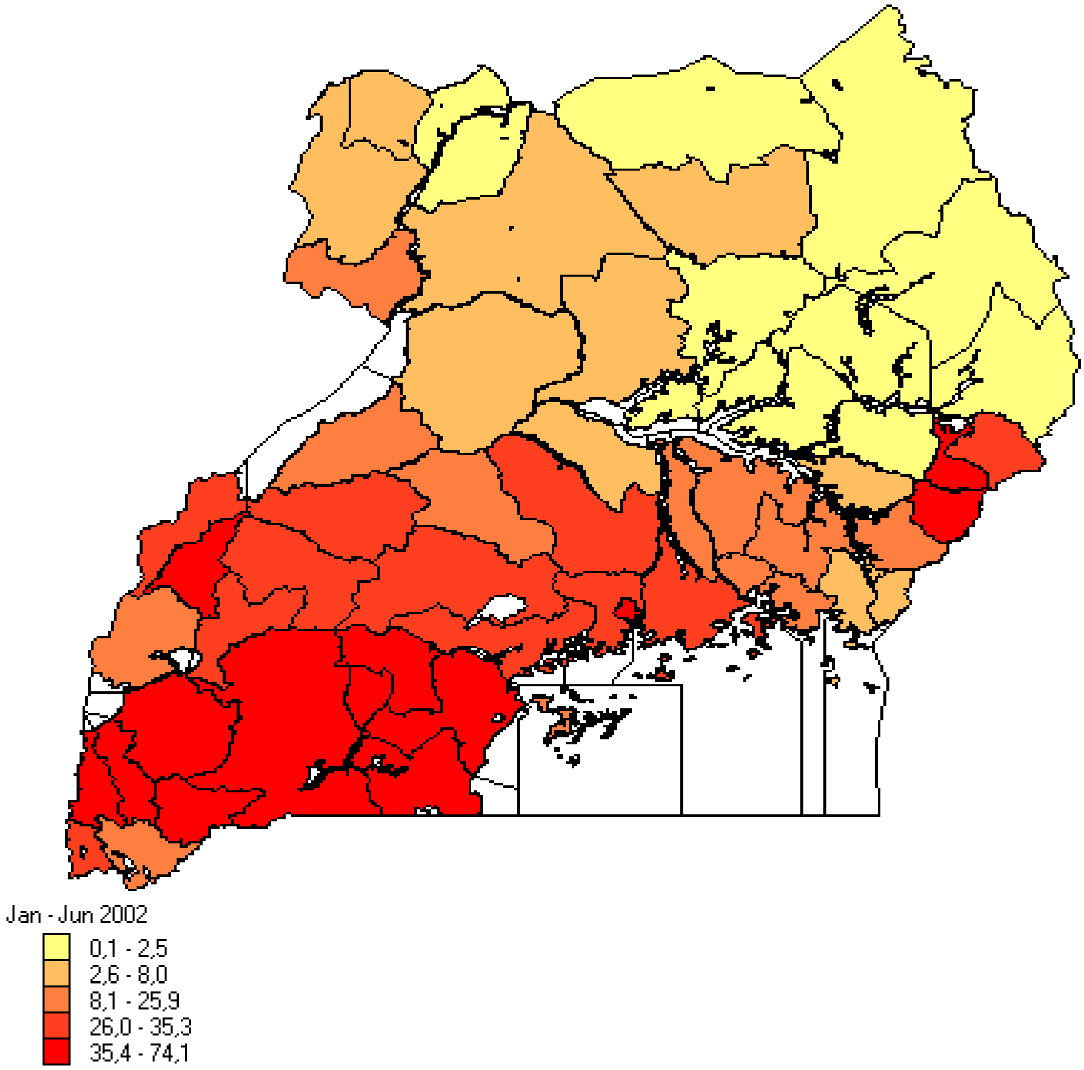

Figure 2. Proportion of agricultural households with banana plots in Uganda (UBOS, 2002)

The banana crop flowers all year round and it is potentially a high yielder, with an annual production equivalent to 8.5 metric tonnes. The crop is less affected by drought than annual crops. The average lifespan of banana plantations is around 14 years, with production peaking between the second and fourth year and gradually declining in subsequent years. The lifespan depends on agro-ecological conditions and management practices. The low-input cultivation of bananas under poor management and infertile soils can cause yields to decline after two years, while with good management practices high yields can be sustained for up to eight years (Robinson, 2000). The life span of banana plantations ranges from as low as four years in the central region to over 30 years in western Uganda (Speijer et al., 1999). Plantations that are over 50 years old exist in the southwestern region[1].

In the past few decades, bananas were a highly sustainable crop in Uganda, with a long plantation life and stable yields. Over the last 30 years banana production patterns have been changing, with acreage increasing or stable in most of the western region, while declining mostly in the Central and Eastern regions. The acreage shift has been attributed to the increasing severity of production constraints, particularly the declining soil fertility, pests and diseases that severely reduced production in some areas (Rubaihayo 1991; Gold et al., 1998). Soil fertility depletion is one of the underlying causes of low agricultural productivity in Sub-Saharan Africa (Sanchez et al., 1996).

Included among the most widespread pests and diseases are weevils, banana nematodes, Black Sigatoka disease, Panama disease or *Fusarium* wilt, and banana bacterial wilt (BBW), which cause significant yield reductions of up to 80 per cent. Weevils are insects that attack all types of banana varieties, although the intensity of weevil damage has been found to decrease with elevation (Gold et al., 1994). Nematodes are root pests that cause root necrosis that interferes with water and nutrient movement in the plant. Black Sigatoka is an airborne fungal disease, which affects the endemic banana varieties. Fusarium wilt is another fungal disease that attacks the roots of banana plants. The exotic brewing varieties are particularly susceptible to it (Gold et al., 1993). Bacterial wilt has emerged as a new and major

[1] The author's father is 70 years old and his current banana plantation was inherited from his father (the author's grandfather).

disease since 2001. Due to its severity, and the fact that presently there is no variety in Uganda that is resistant to the disease, it poses a major threat to banana production in the country.

Drastically declining yields in the historical production areas have led to the replacement of bananas with annual crops and the locus of banana production has shifted to the south-west where biotic pressures are less but the distances to urban markets are greater. Productivity in central Uganda is estimated at six tons/ha, while in the southwest it is 17 tons/ha, which is still low compared to the potential 60 tons/ha attainable at research stations (Tushemereirwe et al., 2001). Despite the decline in production, bananas are still the most preferred staple in many localities, where the word banana is used interchangeably with food, commanding a relatively high price in urban markets.

Available historical data reveal a sharp decline in both output and yields from 1970 to the early 1980s, followed by stagnating national yields (Figure 3). The decline in production in the 1970s and 1980s was largely due to a severe outbreak of banana weevils in the Central Region, then the locus of banana production. The increasing banana production between 1980 and 2003 is largely due to area expansion and the shift in production to the more productive regions in the West. However, banana yields have not recovered to pre-1980 levels, despite intensified efforts to improve productivity through R&D. Clearly, banana producers in Uganda still face major productivity constraints.

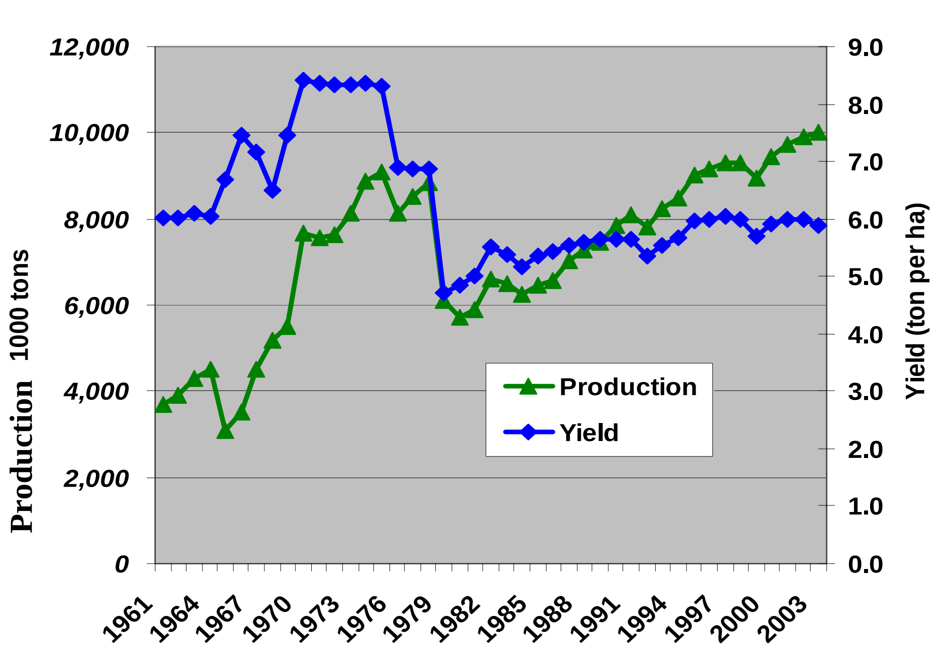

Figure 3. Trend in banana production from 1961 to 2003 (FAO, 2004)

2.3. Banana production management technology

Bananas produced by continuous propagation on the same piece of land demand intensive management to sustain their yield. Both the management of the natural resource base and that related to the crop itself are recommended. Natural resource management practices recommended for banana production include: mulching, manure application and the construction of bands along contours for soil and water conservation (SWC).

Mulching is done with dry organic materials that are spread between the banana mats to suppress weed growth, conserve soil moisture and add nutrients to the soil when the organic materials are decayed. Traditionally, banana plantations were mulched with banana residues (such as old pruned leaves and split pseudo-stems) to suppress weeds, but following the decline in soil fertility, other sources of mulch, including annual crop residues and grass were recommended. Crop residues such as maize stalks, bean trash and sorghum or millet stover are commonly used. In addition to mulching technology, farmers are advised to apply certain other fertilizers to supplement mulch in restoring the nutrients lost due to crop harvests[2]. Other organic fertilizers are applied directly to the soil as organic manure (i.e. animal waste and composted household refuse). Farmers make organic manure from organic materials locally available on the farm. Two types of organic manure are used: dry animal waste or composted crop residues. Composting techniques are less commonly used, perhaps because of their demand on labour or their complexity. Inorganic fertilizers

[2] Although banana residues are recycled, large quantities of nutrients go into the fruit, which are lost when the fruit is sold in urban centers. Even when consumed on the farm, the peels, which contain most of the nutrients, are often used as fodder for livestock (Tushemereirwe et al., 2003).

are also rarely used, perhaps due the to high transaction costs that limit their supply in rural areas (Young, 1994).

The addition of an adequate layer of mulch keeps the plantation surface cool for a long time after rains, which is not only good for the banana plant but also for the banana pests (i.e. banana weevils). Therefore, it is recommended that mulch be applied about 50 cm away from the banana mat (Tushemereirwe et al., 2003). Placing mulch or manure close to the base of the mat can also cause the plant roots to grow towards the surface, making the plant susceptible to wind damage.

Farmers are further advised to carry out a number of other crop management practices to ensure good sanitation in their plantations in order to reduce pest and disease infestation as well as contributing to the good management of their soil fertility. Sanitation practices (hereafter referred to as mat management technologies) include: "corm paring" (removal of the outer sheath from the corm of a sucker before planting it), de-trashing (removal of dry leaves and sheath), de-suckering (removal of excess plants on a mat) and a number of post-harvest residue management practices (stumping, corm removal, splitting or chopping pseudo-stems, and weevil trapping). As in the case of mulching and manure application, farmers must follow certain rules while implementing mat management technologies in order to ensure successful banana production. These rules are practice-specific, making the recommended technologies for improving banana management complex.

Corm paring is a new technique recommended for the control of banana weevils and nematodes. The work should be done in the field where the sucker was obtained to avoid transferring pests to a new field. Furthermore, washing the corm before corm paring is ideal for the effective control of the pests. De-trashing is a traditional technique, involving the removal of the old leaves and sheath. Although it is recommended that leaves should not be removed when still green because they are still useful to the plant, many farmers remove a few green leaves during de-trashing to avoid wind damage. De-trashing contributes to pest and disease control and also provides materials for recycling as mulch. This is done about two to three times a year during rainy seasons but farmers who follow the recommendations may repeat the practice more than three times a year.

De-suckering is also a traditional pre-harvest technology involving the reduction of the number of suckers on a banana mat to reduce competition for water, light and nutrients. With the increased incidence of biotic and abiotic factors, the technique has been modified to cope with the constraints. Farmers are now advised to leave only three plants per mat, with only one plant from each successive generation (commonly referred to as a family, consisting of a mother, one daughter and one granddaughter). Although the practice is widely used, there are notable variations in both the number of suckers left on a mat and the composition of plants on the mat.

Post-harvest mat management practices have also been modified to increase their efficacy in the management of pests/diseases and soil fertility. After harvesting, the stem is cut away at ground level and the stump is covered with a thin layer of soil to prevent invasion by and the breeding of banana weevil. This process is called stumping. The cut stem is split and spread between mats as mulch. There are typically three different methods of splitting the stem, which result in varying levels of effectiveness in pest and soil fertility management.

Given the increase in biotic and abiotic factors and consequent modifications in the banana management technologies, the efforts of banana researchers during the 1990s were directed towards the formulation of operational strategies to address pest/disease problems and create more awareness of the importance of fertility management among farmers. Both on-station and on-farm experiments with the different options were conducted to evaluate the available technology. Scientific experiments conducted on-farm in south-western Uganda indicate that the use of mulch and contour bands can increase banana yields by about 25 per cent, while the use of farm-yard manure can increase yields by about 35 per cent (Oketch et al., unpublished). This is consistent with the observations of other researchers that intensive application of organic fertilizers in the form of mulch (i.e. grass, crop residues or kitchen refuse) or animal manure (i.e. cattle, goat, pig and poultry manure) in banana plantations can improve and maintain soil fertility even when fertility is inherently low (Rubaihayo, 1991; Davies, 1995). These technologies have been disseminated to farmers in a number of different ways.

2.4. Dissemination of banana management practices

Three types of mechanisms have been used in the dissemination of recommended management practices in Ugandan villages: (1) formal sources (government extension services, NGOs, and on-farm research); (2) other farmers; and (3) mass media. The most common and widely used mechanism for information about recommended management practices, in all the production regions, is farmer-to-farmer dissemination (Table 2).

Over 90 per cent of the farmers surveyed reported that they had obtained information regarding banana management from other farmers, and nearly two-thirds were provided with information by formal sources, with 35 per cent receiving it exclusively from other farmers and 56 per cent from both farmers and formal sources. Among the formal sources, government extension was more frequently reported, perhaps due to the wider coverage and the length of time the government has been involved in dissemination. The dissemination of new agricultural technologies in Uganda was traditionally the role of the government extension service, which was joined by some NGOs in the 1990s as part of the economic recovery programme ushered in by President Museveni's government in 1986.

Table 2. Sources of information on banana management practices

Information sources	Percentage of farmers
Formal sources	61.26
• NGOs	22.91
• Government extension	42.76
• Researchers	9.89
Other farmers	90.49
Mass media	25.70
Radio	24.03
Publications	2.83

Source: Survey data, 2003-2004

On-farm research and mass media are relatively new mechanisms introduced especially in the Central region as a strategy to revive banana productivity. As expected, researchers are popular as a source of information in this region because on-farm research intervention has been more concentrated here than in other regions. A quarter of all farmers reported receiving information through mass media. Radios are a frequent source of information in some areas, but publications are rarely used.

Although there is insufficient information to ascertain when most of the banana management practices were introduced to the country, a significant number of them are classified by farmers as ancestral, especially in the south-western and central parts of Uganda. Some of them may be as old as the crop, while others are likely to have arrived during colonial times as management practices for cash crops (such as coffee and cotton) and were later adopted for banana production. Interviews with farmers revealed that the dissemination and diffusion of banana management practices have not been uniform in all three of the production regions. Some practices that are classified as ancestral in one region are considered to have been introduced in another region (see Appendix A), which implies that there are weak interregional linkages.

2.5. Factors affecting banana production

There are direct and indirect factors that affect banana production in Uganda. The direct factors include those already mentioned: the high incidence and intensity of pests and diseases and the decline in soil fertility resulting from high population pressure. The indirect factors include socio-economic factors and the characteristics of the available crop management technologies. These indirect factors are discussed next.

2.5.1. Characteristics of improved banana management technology

As already mentioned in Chapter 1, the principal characteristic of the improved banana management practices is their dependency on farmer resources for implementation. The improved banana management technology typically requires better access to land, labour and management skills. The technology is land-saving on the one hand, and land-using on the other. For example, the use of manure and mulch in banana plantations can significantly increase land productivity (Oketch et al., Unpublished; Rubaihayo, 1991; Davies, 1995) but also indirectly requires access to more land since the crop residues used to mulch or make manure must come from own on-farm production of annual crops (i.e. beans, millet, sorghum, maize) or from livestock, which in turn requires land.

According to Boserup (1965), increases in population pressure and the consequent decline in the land-labour ratio lead to the adoption of techniques of intensive agriculture. In the case of banana production in Uganda, the increase in population pressure has not been matched by increases in the use of techniques such as mulching and manuring, because these practices depend on land availability and household wealth (measured in terms of livestock capital). As the population pressure increases, materials to make mulch and/or manure become scarcer. Instead, more labour is used in controlling weeds, which could be reduced by good mulching. According to Davies (1995), weeding accounts for one-fourth to one-fifth of the time spent in the maintenance of banana plantations. The most noxious banana weeds in Uganda include *Digitaria Scalarum* (blue couch grass) and *Oxalis latifolium* rhizomes. The removal of these weeds requires considerable care to avoid damage to the root system (Rubaihayo, 1991) and is hence labour-intensive.

Another principal characteristic of the improved banana management technology is that it is labour-intensive, but labour availability represents a limiting factor (Ngeze, 1994; Davies, 1995). Although in high-altitude areas cool temperatures may facilitate prolonged working hours, this labour may not be available for banana production, as the time taken to reach the fields, as well as that needed for performing domestic activities (drawing water, collecting firewood), tends to increase with the slope and population density. In addition, the trend towards increased enrolment in schools changes family labour availability. Furthermore, the high number of management practices, and the rules and art of their implementation as described in section 2.3 and in Tushemereirwe et al. (2003), underline the complexity of these practices and the level of knowledge required in banana production management.

2.5.2. Socio-economic factors

Banana is a highly competitive crop in Uganda but its competitiveness depends on the level of management (Bagamba et al., 1999). Thus, factors that affect the choice of management practices influence the returns from the crop. Good crop management indirectly affects crop productivity by reducing the negative effects of the biotic (weevils) and abiotic factors. Farmers' ability to respond to the different biotic and abiotic constraints by adopting good production management practices depends on a number of factors. Land pressure, low incomes, family labour endowment, gender imbalances in terms of access to resources, lack of adequate education and limited access to information regarding production are some of the constraints reported that limit the farmers' ability to effectively deal with the problem of low banana productivity (Bagamba et al., 1999).

Market distortions in both the output and input markets are endemic in Uganda's rural areas. The difference in access to banana markets and hence transaction costs across the major producing areas is evident. The Central Region has comparatively more urban centres, including the three major banana markets of Kampala, Jinja, and Entebbe (Mugisha and Ngambeki, 1994). Populations are also higher in the Central Region compared to the south-western and Eastern Regions. The buyers of bananas from the south-western region face relatively higher transaction costs due to having to travel long distances to the market, which is reflected in low farm-gate prices (Mugisha and Ngambeki, 1994). Therefore, although higher yields may outweigh the higher production costs in the south-western regions (Bagamba et al., 1999), the movement of commercial production to areas further from the principal markets in Central region may not be sustainable in the long run. The perishable nature of cooking bananas limits storage time and their bulkiness makes transportation and marketing very costly. In addition to this, overloading to reduce fixed costs and greater transit time lower the quality of the fruit (Gold et al., 2000). Access to different production zones with varying supply periods may prove important for the reduction of the seasonal fluctuations in banana production (and price) and the diversification of sources of supply (Lynam, 2000).

Increasing production in the Central Region would significantly reduce transaction costs in the marketing of bananas and the farm-gate share of the total price would then be able to increase. However, in addition to soil and biotic constraints, poor management of the crop in this region further limits productivity. Many farmers propagate their bananas using methods that have remained largely unchanged for generations. They focus on weed control and de-trashing to maintain crop sanitation. Most of the practices recommended for banana management are used irregularly and sometimes not at all, which encourages bare soil between mats, where erosion starts too readily and where pests (e.g. weeds, weevils, nematodes, etc.) are allowed to take hold. The direct consequences are low yields and a reduction in the lifetime of the banana plantation.

Aside from physical factors, there are remarkable socio-economic differences across the banana producing regions that could explain the differences in crop production. These differences have not yet been studied. First, market access for banana in the Central Region also implies high market access for all other commodities, which may imply high opportunity costs for investment in banana relative to other crops. Edmeades et al. (2004) concluded that good market access is important to farmers in regard to their choosing which banana varieties to grow, but they did not examine the effect of market access on the use of crop management practices.

Differences are also apparent among the three regions in terms of social characteristics and, implicitly, social capital. These differences may influence the diffusion of information and the ability of households to overcome market constraints, with consequent implications for technology diffusion (Rogers, 1995; Isham, 2000). A high degree of social homogeneity, expressed in terms of domination by one ethnic group[3] and religious affiliation is apparent in high elevation areas (Table 3). Only four out of 20 villages surveyed had less than 50 per cent of households from a single ethnic group, and all were found in the lowlands. According to key informants, the cultural homogeneity in the lowland villages was affected by the importation of labour from other regions to work in commercial crops (coffee, cotton), sugar factories or railway construction during the colonial period.

[3] The concept of an ethnic group cuts across various forms of social organization, including tribe and kingdom, but conveys more of a shared sense of territory and a link to an ecology or food culture than does the term “language group.” Some ethnic groups have lost the use of their language and still remain distinct ethnic groups with a unique ecology and food culture. The term “ethnic group” has no colonial connotations and represents a level of institutions and social organization within and at times across the nation-state. (Pablo Eyzaguirre, IPGRI, personal communication, June 10, 2005).

Table 3. Selected indicators of social homogeneity in the rural villages of Uganda[4]

Indicator	Elevation		All
	Low	High	
Ethnicity (%)	68.50**	95.10**	76.09
Religion (%)	58.20**	67.00**	59.50
Number of ethnic groups	5.40**	2.00**	4.57
Number of religious groups	5.00**	3.80**	4.59

** Significant at 1%

Like ethnic group homogeneity, religious homogeneity is greater in the highlands (67 per cent belonging to a single religion) than the lowlands (58 per cent). How these structures influence technology diffusion depends on which of these attributes most influences the nature and content of social interactions among households. However, no study has been done to examine whether social capital actually influences the adoption of banana management technologies in Uganda.

2.6. Summary

Banana is an important food security crop in Uganda but its production is threatened by the increased incidence and severity of biotic constraints. Yet the use of the crop management practices that have been developed to mitigate the negative effects of these constraints is not as high as expected. A number of social and economic factors are reported to influence management decisions. The effect of other factors such as market access and social capital has not been investigated.

[4] Due to scarcity of information in the literature regarding social processes, the information in this table was gathered from key informants

CHAPTER 3
DETERMINANTS OF TECHNOLOGY ADOPTION

This chapter explores both the theoretical explanations and empirical evidence relating to technology adoption in developing countries. The theoretical context deals with the basic explanations of technology adoption, the conceptual framework underlying the theoretical models of technology adoption and the basic assumptions of these models. The purpose of this chapter is to select the model that best captures the crop management decisions of banana producers in Uganda. A section is also devoted to the model of the agricultural household, reviewing its relevance for the analysis of technology adoption in a developing economy.

The adoption and diffusion of innovations in agriculture has been studied extensively over the last 50 years. The unit of analysis in an adoption study is an individual decision maker (farmer) or decision-making unit (farm household). Diffusion studies refer to the cumulative adoption path or distribution of adoption (percentage of farmers, percentage of area) over time or space, with the community, region, nation or another geographical scale as the unit of analysis. Since the focus of this dissertation is the analysis of the determinants of the use of crop management practices on individual farms and the variations in their use across farms, the literature review will focus on adoption studies.

3.1. Determinants of farm-level adoption behaviour in the literature

Once a new technique of production becomes available, it usually takes some time before it is fully implemented. At the farm level, the transition period may be characterized by a time lag between awareness of the technology and actual adoption or by coexistence of the old and new technology. Economic modelling of technology adoption to explain such adoption behaviour has taken different approaches over time (Feder et al., 1985; Feder and Umali, 1993).

The early modelling of the 1970s emphasized the impact of information and knowledge on the adoption process and the time lag between awareness and actual adoption (Kislev and Shchori-Bachrach, 1973; Hiebert, 1974). Within the empirical framework, information and knowledge were the intervening variables linking the empirical variables with adoption decisions. Differences in adoption rates were attributed to endogenous factors such as differences in skills (Kislev and Shchori-Bachrach, 1973), risk aversion (Hiebert, 1974) and prior beliefs (Feder and O'Mara, 1982). An innovation was conceptualised as first adopted by high-skilled and experimenting farmers and later diffused to low-skilled farmers as experience with the technology accumulated in the community (Kislev and Shchori-Bachrach, 1973). Education, through its positive influence on "the ability to perceive, identify, acquire, process information and respond to new events in the context of risk" (Schultz, 1975), was associated with early adoption of new technologies.

Similarly, risk preferences were identified as the determinant of adoption rates. Early adoption was associated with risk neutrality and late adoption attributed to risk aversion (Hiebert, 1974). Learning and information accumulation reduce uncertainty, making the parameters of the production function under the new technology, as perceived by farmers, shift from a low to a high pay-off, thereby persuading the potential adopters who are more risk-averse to also adopt (Hiebert, 1974).

In the light of the uncertainties (i.e. production, price or availability) associated with the new technology, much of the empirical analysis throughout the 1970s and early 1980s focused on the role of risk in the adoption process. Risk aversion reduces adoption because the risk-averse producer stops short of maximizing expected income when the variance of net income increases as the expected net income increases (Hiebert, 1974). Hence, a risk-averse farmer will trade off high yield (or profit) for low variability so as to reduce the extent of risk. A range of specifications and decision rules to depict farmer behaviour under risk and uncertainty were proposed and applied. The impact of both the objective and subjective risk was examined.

One widely used approach was that of portfolio selection formulation (Just and Zilberman, 1983), in which optimal decision depends on the mean, variance and covariance structure of the introduced and locally grown varieties. Under uncertainty, farmers maximize the expected utility of income or profits by choosing the level of variables they control, which can result in partial land allocation to the new technology rather than complete adoption.

In the case of risk neutrality, differences in the adoption rates were attributed to differences in prior beliefs about the new technology (Feder and O'Mara, 1981). Adoption of a new technology starts with farmers holding more positive prior beliefs about the profitability of a new technology because they do not need much information to be convinced compared to those who hold less favourable beliefs. With time, potential adopters update their beliefs about the profitability of the new technology with the new information generated by early adopters and are hence induced to adopt.

Other studies conducted in the 1980s show that farm-to-farm differences in the rate of adoption or extent of adoption of a new technology might be explained by other considerations. Transaction costs involved in learning and acquiring the new technology that are independent of scale were identified as important impediments to the rate of technology adoption (Perrin and Winkelmann, 1976). Because the fixed cost per unit of land decreases in scale, there is a threshold of farm size below which it is less profitable to adopt a technology (Feder and O'Mara, 1981). The fixed costs will be high if the subcomponents are forever changing to adapt to the changing environment or new components being introduced where decision makers have low levels of human capital (Schultz, 1975), as is often the case in developing economies. This critical farm size decreases over time as uncertainty is reduced because of learning and the dissemination of information from early adopters.

Credit constraints were also identified as an impediment to technology adoption in developing economies (Feder et al., 1985). Technologies introduced to increase agricultural productivity are often accompanied by increases in the input requirements, which may not be affordable to some farmers or readily available in specific locations. Even when the technology is neutral to scale and the presumable fixed pecuniary costs not large, credit constraints will limit adoption (Feder et al., 1985). Farmers will allocate land to the new technology up to the point where credit is binding and partial adoption will result.

Farm size emerges from the empirical studies of the 1970s and 1980s as an important surrogate for a large number of factors such as access to credit, capacity to bear risk, access to inputs, wealth, and access to information (Feder, 1980; Feder and O'Mara, 1981; Just and Zilberman, 1983). The fixed transaction costs decrease with an increase in farm size, which explains why the adoption of new divisible technology might begin with larger farmers. Second, because larger farmers have a greater ability to raise capital, to bear the cost of the innovations and to bear the risk of failure, they are likely to be less risk-averse compared to relatively small farmers and are more likely to make risky investments compared to smaller farmers.

The impact of complementarities between the interrelated innovations within a package on adoption behaviour was also examined (Feder, 1982), reflecting the way in which innovations were promoted at the time (seed, fertilizer, agronomic practices). Sequential adoption of individual components of a technological package was explained in light of risk and input scarcity (Byerlee and de Polanco, 1986). Further studies on sequential adoption behaviour were reviewed by Feder and Umali (1993).

In other studies, the static models were made dynamic by incorporating the “learning by doing” aspect of the adoption process. The Bayesian approach was used by a number of authors. For example, Leathers and Smale (1991) invoked Bayesian learning to explain why the step-wise adoption of components of a technical package can occur even in a risk-neutral context without credit constraints. This literature suggests that the main reason farmers may experiment with the technology is to develop skills on how to implement the technology and/or reduce uncertainty about its actual profitability. This is important when the technology is knowledge-intensive and/or the outcome is less obvious to the potential adopters. Within this framework, the adoption decision involves choosing an adoption path that will maximize the expected utility from a stream of profits, subject to a bounded rate of adoption. The impact of expectations on future prices also received attention in the dynamic modelling of technology adoption, where Tsur et al. (1990) likewise maintained the assumption of risk behaviour.

In some cases, advancing any single explanation against another can lead to biased results and policy recommendations. In the case of hybrid maize in Malawi, Smale et al. (1994) demonstrated that no single explanation (i.e. portfolio diversification, safety-first, experimentation or input fixity) explained the land allocation decisions to new varieties, and proposed a nested model that includes all four major explanations as special cases.

It is critical to recognize that the models and approaches generated in early adoption studies reflect the type of technology and the institutional context of the green revolution (high-yield crop varieties and complementary inputs such as fertilizer, pesticides and timely planting practices). Both of these factors differ in important ways in this study. The institutional differences are mentioned in Chapter 1, involving a shift from the top-down, centralized, traditional model of research and extension. The major point of contrast with respect to technology is that the green revolution technologies were composed of largely external inputs that were disseminated to communities as physical technologies (seed, fertilizer). On the other hand, improved banana management practices are low external input technologies that rely on local resources for their implementation. Because these are knowledge-based and depend on local resources, they are knowledge-intensive and farm-specific (Lee, 2005). With the improved banana management technology, only information is disseminated to farmers. The actual physical technology (i.e. mulch, manure) is made on the farm by combining local resources (typically labour and by-products of other farm activities) with the acquired knowledge. Therefore, unlike the green revolution technologies, the improved banana production management technologies demand more of the farmer's local inputs and management capacity for their successful adoption, implying that the factors that influence their adoption may not necessarily be similar to those that were important in the adoption of green revolution type technologies.

Second, the green revolution technologies were applied to annual crops, while the improved banana production management technologies are used on a perennial crop, and hence have cumulative effects on the yield. This has implications for the modelling of decisions to be made by these farmers. For example, when a farmer is deciding on whether to apply the improved banana production management technology, he/she must not only look at the crop productivity as it is at the present but also as it will be in the future as a result of the cumulative effects. As such, the use of on-farm labour and non-labour inputs can be viewed as investments in systems that will presumably yield a time-path of positive anticipated benefits if adoption occurs

(Lee, 2005). When the crop is valued as an asset that can be passed on to coming generations, then the household composition is likely to come into play in making crop management decisions.

3.2. Determinants of the adoption of low external input crop management technologies

In the post-green revolution, there has been an increasing interest in agricultural systems that employ a reduced use of external off-farm inputs (inorganic fertilizers, pesticides, mechanical inputs), and in the use of improved management techniques and practices. This interest originates from a number of sources outlined in Lee (2005). To mention but a few examples, one of the related concerns has been the affordability of the external input (i.e. fertilizers, pesticides and mechanical inputs) whose price and/or lack of accessibility often make them unavailable or unaffordable to resource-poor farmers. Another source of interest has been the environmental effects of modern agriculture, and impacts such as pesticide contamination, deforestation and the degradation of ground water and surface water resources, which threaten environmental quality.

Low external input technologies have been commonly developed for land management and integrated pest management. The land management technologies (such as agro-forestry, alley farming and zero or minimum tillage) can be applied in the production of any crop on the farm, while integrated pest management technologies are often crop-specific. The improved banana production management technologies investigated in the present study cut across these two subcategories. Some components involve land management techniques (such as mulching, and manure application) while others, e.g. sanitation of the mat, are dual-purpose. For example, de-suckering and post-harvest management of banana residues is useful in the control of pests and diseases but also facilitates the recycling of nutrients and the maintenance of the soil nutrient status. The adoption of low external input technologies has been well documented (for a detailed review see Lee, 2005).

The properties or characteristics of low external input technologies are one of the most important determinants of adoption patterns. The role of technological characteristics in determining the rate of technology adoption was established in earlier adoption studies (Rogers; 1983, 1995). Rogers (1995) hypothesized five technology attributes, as perceived by potential adopters, that affect the rate of adoption, namely, (1) relative advantage: the degree to which an innovation is perceived as being better than the idea it supersedes, whether measured by economic or social criteria or its convenience or the satisfaction it provides; (2) compatibility: the degree to which an innovation is perceived as being consistent with the existing values, past experience, and needs of potential adopters; (3) complexity: the degree to which an innovation is perceived as being difficult to understand and use - innovations that require more skills-building and learning would be more complex than innovations that are less knowledge-intensive; 4) trialability: the degree to which an innovation may be experimented with on a limited basis. (Innovations that are easy to experiment with on a partial basis are adopted more rapidly than innovations that are less easy to experiment with. Lump-sum innovations, for example, would be difficult to experiment with since one cannot acquire them in small units, whereas divisible innovations would be easy to experiment with); and (5) observability: the degree to which the results of an innovation are visible to the potential adopters.

In the light of the first two technological attributes, the location-specific nature of the low external input technologies puts a premium on their adaptation and appropriateness in meeting the agro-ecological and social-economic conditions relevant to specific regions, consequently limiting the set of farming constraints they can address in both biophysical and economic environments (Lee, 2005). For example, Adesina et al. (2000) show how a technology technically developed to enhance the physical environment was adopted due to its complementary economic attributes. In south-western Cameroon the authors found that farmers in villages facing a fuel wood scarcity were more likely to adopt alley cropping systems over conventional bush fallow rotations compared to farmers who did not face such constraints. Also, biophysical factors figure prominently in influencing the adoption patterns for integrated pest management, agro-forestry and soil conservation in Central America (Ramirez and Schultz, 2000). Shiferaw and Holden (1998) show that the adoption of conservation technologies is likely to increase with the slope of the land. Clay et al. (1998) find evidence that farmers in Rwanda tend to invest in soil conservation on slopes of medium grade.

The relatively high labour intensity of the low external input technologies has also been recognized (Lee, 2005). Generally, the seed-fertilizer technologies of the green revolution were hypothesized to be more labour-intensive than traditional varieties and practices. Unlike the green revolution type technologies, however, the low external input technologies tend to substitute labour for capital (high external inputs). This means that the availability of family labour, labour market imperfections and credit constraints all affect the adoption of low external input technologies. For example, Ersado et al. (2004) found that the health status of farm family members influences the adoption of productivity and land-enhancing technologies in northern Ethiopia. Market imperfections are also identified as important determinants of the adoption of low external input technologies (Shiferaw and Holden, 1998).

Many of the low external input technologies are complex. The adoption of improved banana management technology, to cite one example, involves a wide range of management decisions. The farmer has to decide as to whether to apply the technology or not, which practices to use for which constraint (i.e. match the appropriate technique with the respective constraint), which method to use and how to use it in implementing each technique, as well as the timing of the techniques (Tushemereirwe et al., 2003). The combination of the techniques and the timing of their labour inputs must be well managed to be optimal (Tushemereirwe et al., 2003). Such decisions require a high management capacity that may not have been so critical in the adoption of green revolution type technologies.

The management capacity of the farmer depends on a number of factors but probably no factor is as important in improving management skills as information dissemination and the knowledge it generates. Information may create a problem awareness that marks the beginning of change in the management system, including technology adoption. There is evidence that farmers' perceptions of soil erosion or fertility decline encourage the adoption of soil conservation practices and land productivity enhancing technologies (Ervin and Ervin, 1982; Shiferaw and Holden, 1998; Mbaga-Semgalawe and Folmer, 2000).

3.3. The role of institutions and social networks in adoption decisions

The critical role of management capacity and information in the adoption of low external input technologies means that the mechanisms through which information and knowledge are developed, transmitted and diffused are critical to these systems. Information about a technology can come from own experimentation and/or external sources. Information from external sources comes from formal institutions such as public sector extension services, non-governmental organizations (NGOs), the mass media, or through informal mechanisms such as farmers' organizations or networks of friends, relatives and acquaintances. Various sources of information have varying costs and, depending on the economic, social, location and demographic characteristics, different potential adopters may prefer different sources of information (Wozniak, 1993).

Institutions play a role at all levels, as in the high external input technologies (Lee, 2005). However, in developing economies, formal institutions are constrained by inadequate funding for public extension and most farmers rely on informal mechanisms for information about new technologies. The fact that farmers learn from other farmers underlies most studies of social learning in the adoption of agricultural innovations. Literature indicating the importance of social learning regarding technology adoption is extensive (e.g. Foster and Rosenzweig, 1995), but most of these studies do not explain how the information is diffused from early adopters to potential adopters. Nevertheless, as Montgomery and Casterline (1998) maintain, information about choices is likely to be drawn from the individual's social network rather than from the whole village. Conley and Udry (2001) also demonstrate that information generated by early adopters diffuses through sparse social networks, contrary to the assumption of free availability in the whole village.

Rogers (1995) identifies four key aspects of communication behaviour that encourage the adoption of innovations: (1) greater social participation, (2) a high level of interconnectedness, (3) being more cosmopolitan, and 4) opinion leadership. However, few economic studies on technology adoption have included such social factors in the econometric models of technology adoption, perhaps because they are not easily measured. Social capital has usually been linked to information diffusion

(Narayan, 1997; Collier, 1998), leading to a growing interest in social capital as a means of facilitating the adoption of new technologies (Isham, 2000).

3.4. Agricultural household models and technology adoption

The models developed in the early studies of technology adoption were conceptualised within the neoclassical theory of production. Within the neoclassical theoretical framework, profit maximization is assumed to be the only objective underlying the production behaviour. Factor allocation decisions are based on marginal productivity, which is assumed to be uniform across farms (producers). By assuming profit maximization, the modelling of household decision making postulated the existence of perfect markets for output and input goods, including labour and credit, thus implying that production and consumption decisions are recursive (Singh et al., 1986; de Janvry et al., 1991).

When all markets work and all prices are exogenous, the household decision making process becomes recursive and the profit maximization assumption is appropriate for analysing production behaviour. When not all markets work, the production and consumption decisions are interdependent (Singh et al., 1986; Sadoulet and de Janvry, 1995; Taylor, 2003), which inevitably makes the farm household's production decisions dependent on its consumption demand.

Perfect market conditions are rare, particularly in developing economies. Although this problem was recognized, few attempts were made in the early adoption literature to formally model the impact of market constraints on the adoption of new technologies. In particular, market imperfections arising from high transaction costs were ignored. The focus was more on the role of profits and risk in technology adoption. The role of risk was incorporated by assuming that farmers maximize expected utility over income or profits (Just and Zilberman, 1983). Subsistence production was dealt with under risk behaviour and analysed using safety-first approaches (Hammer, 1986).

Increasingly, the starting point for micro-economic research on small-farm economies, whether theoretical or applied, is an agricultural household theoretical framework. One of the earliest agricultural household models is associated with Chayanov (1925) cited in Singh et al. (1986). Chayanov used his model to examine the relationship between labour allocation to on-farm production and leisure by the peasant households. He observed that peasant households were not simply maximizing profits but rather had a subjective equilibrium within which they equated the utility of household consumption with the marginal utility of leisure. He showed that, in the case of poor labour markets, on-farm labour supply was a function of household demographic factors (i.e. household size and composition) rather than the wage rate, as in the case of perfect market conditions. Since his analysis the agricultural household model has evolved in a variety of ways and has been applied extensively to analyse household consumption, production and labour supply behaviour. Some of these studies are reviewed in Singh et al. (1986).

The key feature of agricultural household models is the non-separability of the production and consumption decisions. The issue of separability depends on whether or not there is a difference between the market prices of production-consumption goods and their “shadow price” within the household (Sadoulet and de Janvry, 1995; de Janvry et al., 1991). Household production and consumption decisions cannot be separated unless the decision price is exogenously determined in the market. When the shadow price is endogenously determined by the interaction between household demand and supply, consumption choices affect production decisions. Consumption and production decisions are said to be “non-separable”. Price endogeneity may arise under a number of circumstances (Singh et al., 1986; de Janvry et al., 1991; Sadoulet and de Janvry, 1995). It may be present due to production risks (Roe and Graham-Tomasi, 1986), price risk (Saha, 1994a; 1994b), or the high transaction costs that are endemic to poor economies (de Janvry et al., 1991; Edmeades, 2003).

High transaction costs in the rural areas of most developing economies result from the high transportation costs associated with poor infrastructure and long distances from the markets (Binswanger and McIntire, 1987; Sadoulet and de Janvry, 1995). The existence of transaction costs implies that even if a perfect market for the commodity existed in a particular distant location, agents would have to incur high costs to access this market, thus creating a wide band between the sale price and the purchase price. A household facing a wide price band for a particular commodity or factor may prefer to be self-sufficient in that commodity or factor when the gains from participating in the market are less than the transaction costs. Although there may be extreme cases of a complete absence of markets, in most cases a market for a commodity exists in which some households may participate while others do not. Hence, market failure is characterized as household-specific rather than commodity-specific (de Janvry et al., 1991).

In the literature, most of the agricultural household models that examine the impact of market constraints on household behaviour take the household as acting independently of other households. Prices are endogenously determined by equating the household's demand with its own supply. The household is assumed to have fixed time, cash endowment and other productive assets. The role of social networks as an alternative productive asset through which the supply of goods and services (i.e. income or information) can be accessed has not been formally incorporated in agricultural household modelling despite its recognized role in overcoming transaction costs (Binswanger and McIntire, 1987; Bromley and Chavas, 1989; Fafchamps and Minten, 1999). With high market transaction costs and constraints in formal institutions, the exchange of goods and services among households in developing economies is known to take place within social networks (Bromley and Chavas, 1989). Therefore the present study attempts to extend the basic household model by allowing the household's exogenous income and knowledge accumulation process to be functions of social capital.

3.5. Summary

With the high population growth rates relative to the growth in agricultural productivity in Sub-Saharan Africa, problems associated with technology adoption have come increasingly to the fore. In the Ugandan agricultural sector, many important questions regarding technology adoption and agricultural productivity are evident. It has been the purpose of this chapter to cover most of these issues in an introductory manner. The objective is to establish key elements to be used in the economic analysis of technology adoption in the Ugandan banana sub-sector.

Among other things, the incidence and extent of technology adoption is determined by the nature of the technology. If the new technique is knowledge-intensive, its inter-farm and intra-farm adoption will be slow and most likely biased towards those with better access to information. The extent and pattern of adoption of scale-neutral technologies is also subject to their technical and economic properties as evaluated according to the endogenous as well as exogenous factors characterizing the potential adopters. However, the nature of the technology is not the only determinant of technology adoption. Other social, economic, institutional and physical factors may intervene in the process. Technological change can therefore be biased towards certain producers even where the innovation involved is not of a highly capital-intensive type.

This chapter has also suggested that where market imperfections impede the participation of households in markets and hence economic decisions, social capital may be drawn upon to reduce the consequent transaction costs. Economic studies that explore the efficacy of social capital in shaping household production behaviour are still rare. Given the importance of social capital in this study, the next chapter will be devoted to exploring this concept in more detail, as well as the mechanisms through which it may influence adoption decisions.

CHAPTER 4
SOCIAL CAPITAL AND TECHNOLOGY ADOPTION

In the previous chapter social capital was identified as a variable that intervenes in the technology adoption process. This chapter extends that analysis by explicitly recognizing social capital as a factor that may influence technology adoption through its effect on household resources and access to information about new technologies. An overview of the literature on social capital is given, focusing on the manifestation and definitions of social capital and the conceptual issues surrounding it in the literature. The purpose of this is to develop an appropriate conceptualisation and means of measuring social capital in rural Uganda. A section is also devoted to the determinants of social capital, based on the literature survey.

4.1. Manifestations and definitions of social capital in the literature

The concept of social capital has been used to describe a wide range of phenomena, but different definitions exist. While different definitions enable a wide application of the concept, this has also constituted a limitation on the development of a theory of social capital. Most scholars who have sought to incorporate the concept in economic analysis have done so while acknowledging that it has not yet intellectually matured. Divergent definitions and perspectives have also raised certain questions and criticisms. For example, Bowles (1999) argues that social capital is an inappropriate term for the idea it is supposed to represent, while Arrow (2000) even suggests that the term “social capital” should be abandoned. These concerns are understandable given the conceptual weaknesses in the literature on social capital.

Research on social capital is characterized by ambiguities regarding who owns social capital. Some studies conceptualise it as a community attribute (Narayan, 1997; Putnam, 1993) while others focus on individuals as the “owners” and benefactors of social capital (Coleman, 1988; Portes, 1998). Issues of who owns social capital aside, it is not clear whether the direction of formation runs from the micro (individual) to the macro (community) level or vice versa. Thirdly, social capital is always defined by its functions, thus setting aside its negative aspects and externalities (Arrow, 2000).

Despite the conceptual weaknesses, there is considerable consensus that social capital has some characteristics that qualify it as “capital”. Accumulating and maintaining a stock of social capital, like other forms of capital, takes time and other valuable resources. Similarly, social capital and human capital depreciate if not used, but not with use. A relationship with an individual with whom you never interact may not be reliable in times of need. Collier (1998) presents a detailed argument on how social interactions produce persistent economic effects that qualify social capital as capital.

Social capital also has features that distinguish it from other forms of capital. Social capital is neither lodged in the actors themselves nor in the physical implements of production but is inherent in the structures of relationships among actors (Coleman, 1988). While every other form of capital has a potential impact in a typical Robinson Crusoe economy, social capital does not. Creating and activating social capital requires at least two people. As such, social capital has certain characteristics of public goods, implying that it is not completely internalised and will be under-produced in the economy.

4.1.1. Manifestations of social capital

Social capital manifests in two broad forms: structural and cognitive (Dasgupta, 2000; Uphoff, 2000). In terms of morphological characteristics, the structural form of social capital is extrinsic and observable and is associated with various forms of social organization, such as roles, rules, precedents and procedures, as well as social networks. On the other hand, the cognitive form of social capital exists in people’s minds and is hence unobservable. In its cognitive form it refers to norms such as trust, shared values and beliefs. In terms of its functions, Uphoff (2000) describes the role of the structural form of social capital as concerned with facilitating information sharing and collective action through established roles, social networks and other social structures that lower transaction costs, while the cognitive dimension predisposes people towards cooperation and collective decisions.

From the above discussion, the complementary role of the two forms of social capital is evident. According to Uphoff (2000), the two forms interact to produce a single stream of benefits. A synthesis of the various definitions of social capital also reveals that there are more similarities than differences between them (Haddad and Maluccio, 2003; Paldam, 2000; Durlauf and Fafchamps, 2004).

Haddad and Maluccio (2003) point out three similarities: (1) Most of the definitions agree that individual social interactions are at the core of social capital. (2) Nearly all agree that while social interaction takes place at the individual level, social capital has the potential to generate externalities. (3) Most definitions acknowledge that the mechanisms that drive social capital have to do with information transmission, the establishment of trust, and the development of norms of collaboration. Paldam (2000) classifies the various definitions into three families of social capital concepts: (1) trust (2) ease of cooperation and (3) networks. He observes that while the three families lead to different definitions and measurement methods, they are all related in that they tap the same latent variable. He concludes, "…the choice of the definition is a matter of convenience". Durlauf and Fafchamps (2004) distinguished three main ideas underlying the definitions of social capital, two of which are similar to what Haddad and Maluccio (2003) observed: (1) Social capital generates positive externalities for the members of a group, (2) these externalities are achieved through shared trust, norms and values and their consequent effects on expectations and behaviour, and (3) shared trust, norms and values arise from informal forms of organization based on social networks and associations.

The conceptualisation of social capital in the present study follows the structural dimension of social capital because it is observable and hence easy to measure. Second, its role in information diffusion and other social resources makes the structural component more relevant to this study. Most definitions of social capital that follow the structural dimension are based on social networks or their components, as discussed below.

4.1.2. Social network definition of social capital

Social capital has been defined both at community level and at individual level. At community level, the structural component of social capital has been defined in terms of the density and diversity of associations (hereafter referred to as institutionalised social networks) within a community (Putnam, 1993; Narayan, 1997). The associational interactions in the community reflect the ability to coordinate, monitor and hence solve a collective dilemma. At the individual level, structural definitions consider social capital as embedded in the network of friends, relatives and acquaintances (hereafter referred to as private social networks[1]) an individual interacts with, based on "norms of reciprocity" (Lin, 1999; Fafchamps and Minten, 1999; Glaeser et al., 2001). Although institutionalised social networks could also be composed of friends or relatives as members, they differ from private social networks in their structure and functioning.

The concept of a private social network, as used in the present study, is a spontaneous free interaction of people organized in dyadic relationships without a defined membership. A dyadic relationship exists between only two people linked to others in a continuous chain. On the other hand, the term "institutionalised social networks" (also referred to as "association") refers to a collection of more than two people who join together to advance a common interest. The common interest may take the form of sharing one or more of the following: production costs, member characteristics or a good characterized by excludable benefits (Cornes and Sandlers, 1986). As compared to a private social network, an association has an organizational form and a defined membership (Collier, 1998), irrespective of degree. Collier (1998) also distinguishes associations from dyadic social relationships by the fact that the latter lack the capacity for group decision-making that characterizes institutional social networks.

The emphasis on the measurement of both the quantity and quality of social interactions is common to most social network definitions. The bridging or bonding nature of social capital (Narayan, 1997; Woolcock and Narayan, 2000) or the valued resources embedded in the private social network (Lin, 1999; Fafchamps and Minten, 1999) is measured along the qualitative dimension. Social capital is described as bonding if relationships facilitate intra-group interactions or intra-community ties, and as bridging where interactions strengthen links between groups (inter-community) and other actors or organizations (Putnam, 1993; Woolcock and Narayan 2000; Svendsen and Svendsen, 2004). In a sense this distinction is more apparent than real. For

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[1] Private social networks have also been referred to as informal networks, while associations are referred to as formal social networks (Godquin and Quisumbing, 2005).

example, bonding along ethnic lines can be a bridging mechanism when looked at from an economic point of view. Likewise, a successful bridging relationship can ultimately break down more pronounced distinctions and so become a bonding relationship when examined along a different axis. Hence the classification depends on the focus of the study. The nature of social capital in the present study is investigated along the social and economic dimensions.

Most of the social network definitions of social capital existing in the literature have considered either the institutional social networks (Putnam, 1993; Narayan, 1997; Narayan and Pritchett, 1999) or private social networks (Lin, 1999; Fafchamps and Minten, 1999; Glaeser et al., 2001), but not both. Social networks also have components, and focusing on only one component fails to capture the interactions between them, which could result in biased estimates of the structural social capital in a society. In the present study a social network definition that encompasses both "institutionalised social networks" and "private social networks" is used. Borrowing from the definitions of Narayan (1997) and Lin (1999), social capital is defined as the density and diversity of institutionalised and private social networks based on mutual trust and norms of reciprocity.

This definition is consistent with the idea that social capital that affects the optimising behaviour of economic agents and can increase or (decrease) output is embedded in social relationships that can exist either at the community or the individual level. Therefore, individual social capital can be conceptualised as consisting of two components: (1) the private component that is embedded in friends, relatives and acquaintances, and (2) the public or social component that is embedded in the community and flows from informal community institutions (local associations). Although some associations are designed to solve specific economic problems and have characteristics of excludable club goods (Cornes and Sandlers, 1986), these same associations generate externalities, such as increased information diffusion, that will affect many in the community (whether or not they are members) and hence qualify as a property of the community.

In addition, social capital as defined in the present study is neither good nor bad, contrary to the argument that social networks that generate negative externalities should be excluded from consideration as social capital (Durlauf and Fafchamps, 2004; Collier, 1998), but consistent with the reality that externalities from social networks are not mutually exclusive (Portes, 1998; Woolcock and Narayan, 2000). Finally, the definition is also consistent with the conclusion of Woolcock and Narayan (2000) that in order to avoid making tautological claims regarding the efficacy of social capital, the measurement of social capital should endeavour to capture its two basic dimensions: bonding and bridging social relationships.

4.2. Social networks and technology adoption

Informal institutions and private social networks play three distinct roles in the adoption of crop technologies (Hogset, 2005). First, they act as conduits for financial transfers that may relax the farmer's credit constraints. Second, they act as conduits for information about the new technology. The information may relate to new methods of farming, new crop varieties or a problem concerning agriculture in the area (Collier, 1998). As demonstrated in Chapter 3, improved banana production management technologies (i.e. mulching, manure application and sanitation practices) fit the description of being knowledge and labour-intensive, which may make social networks important in their adoption.

Thirdly, social networks can facilitate cooperation to overcome a collective action dilemma where the adoption of technologies involves externalities. An example of such collective action is the practice of uprooting and destroying banana mats infested with bacterial wilt to stop the spread of the disease in the community. At the individual level, the benefits from the practice are low or may even be negative if the banana plantation is severely affected by the disease. But at the community level the benefits are high if the disease is controlled and the crop does not become extinct. Because externalities are not internalised by economic decision makers there would be "too little" farm-level adoption of such practices in the absence of external intervention. With such technologies, the adopting unit is the community, involving all members to internalise the benefits of the technology. The success of such collective decision-making depends on the existence of social capital among the community members to act as a lubricant in the process. Since no serious externalities are anticipated in the use of mulching, manure application and sanitation, the mechanism of collective action is not investigated in the present study. The first two mechanisms through which social capital may influence the use of improved banana production management technologies are discussed below.

4.2.1. Social network and information accumulation

In Chapter 3 it is demonstrated that information plays a key role in the adoption of agricultural technologies. Information is particularly important when technology is complex (in terms of knowledge-intensiveness) and its components are forever changing to adapt to the changing environment (Schultz, 1975). The improved banana production management technology in Uganda has been subjected to adjustments over time to cope with increased biotic and abiotic pressures. Yet the formal education of the majority of farmers is limited (an average 5.8 years of schooling), which makes the mechanisms through which information is disseminated and diffused crucial in understanding the adoption processes in the case of these technologies.

In most developing economies, farmers operate in environments where the high cost of operating programmes curbs the capacity of the government to provide adequate extension services to all farmers. In Sub-Saharan Africa, the structural adjustment programmes implemented from the 1980s onwards further reduced access to agricultural extension educators. Although they have always been regarded as important sources of information about new technologies, farmer experimentation and social learning are now primary.

The role of social learning in technology adoption has been demonstrated (Kislev and Shchori-Bachrach, 1974; Feder and Slade, 1984; Foster and Rosenzweig, 1995). Foster and Rosenzweig (1995) present evidence that farmers with experienced neighbours devote more land to new technologies. Pomp and Berger (1995) found evidence that copying others was an important determinant in the adoption of cocoa in Indonesia. Their study shows that increases in the proportion of adopters in a village improve the likelihood that a potential adopter in that village will adopt. As observed by Isham (2000), the classical studies of social learning did not analyse the variables that intervene in social learning. One would expect social capital to be crucial in regulating information diffusion from adopters to non-adopters. Farmers may actively seek information from their neighbours or learn passively from others within their social structures during social interactions.

Yli-Renko et al. (2001) indicates that internal and external social capital contributes to knowledge-based competitive advantage in firms. The analogy to a village is straightforward. Bonding social capital within a village increases information diffusion among farmers within that village, while bridging social capital enables the village to access information from external sources (Woolcock and Narayan, 2000; Isham, 2000). Yet it is also true that such forms of social capital are not uniformly distributed across locations, which could bring about differentials in access to social learning and hence technology adoption.

Collier (1998) identifies two mechanisms through which social interaction can generate information externalities: One-way social interaction (observation of other people's behaviour) and the two-way mechanism (pooling information), which is common in horizontal social networks. In rural settings, where formal information systems are inadequate, social capital may supplement them.

Contrary to Collier's (1998) one-way social interaction, but consistent with the two-way social interaction mechanism, Rogers (1995) views technology diffusion as a process mediated through the two-way process of communication convergence rather than as a one-way linear act, emphasizing the role of face-to-face interpersonal interaction in technology diffusion. He concludes that interpersonal networks are the most important source of information for late adopters, serving two roles: diffusion of information from the early adopters to the potential adopters and persuasion of the latter by the former to adopt the technology. Persuasion arises because individuals are themselves members of a larger group. The information that is held by group members, the choices they make and the outcomes that flow from them can all exert a powerful influence on individual incentives to innovate. Montgomery and Casterline (1998) assert that the power that individuals exercise over each other through authority, respect and social conformity pressures influences the choices they make. Moser and Barrett (2003) find evidence that the pressure to conform to community norms has a significant influence on farmers' technology choices.

Social networks may serve as complements to more formal sources of information and sometimes as substitutes. When new information about technologies is introduced into the community through formal channels (mass media or extension educators), the social networks help to diffuse it. Members of the social system can also introduce new technologies into the social system through their weak social ties (Granovetter, 1973). In this case, social networks can completely substitute for formal channels of communication at a smaller-community (village) level but complement it in a wider community.

The amount and content of information one can get from the social networks in any period depends on the quantitative as well as qualitative properties of the social networks (Isham, 2000; Lin, 1999). Rogers (1995) identifies three qualitative properties of a social structure, e.g. of the social networks that promote information diffusion within a community: the degree of homogeneity, leadership, and social norms. The heterogeneity of village leaders captures the idea that community leaders often act as opinion leaders and that their heterogeneity in terms of education and income makes them a good link between the community and external information sources: e.g. agricultural extension systems, mass media or other farmers in other communities, exploiting the "strength of weak social ties" identified by Granovetter (1973). The strategy adopted by opinion leaders often depends on the prevailing social norms in the community. If the community favours change, then it is in the interest of opinion leaders to adopt new technologies rapidly in order to maintain their social status and position as opinion leaders (Rogers, 1995). Hence social norms can complement the role of opinion leadership in technology adoption.

The effect of social homogeneity on information diffusion and hence technology adoption is twofold. First, it facilitates communication between individuals and hence effective exchange of information. The extent to which any two people who are communicating have similar attributes and beliefs affects information sharing because communication between them is more likely to be effective if they have similar attributes and beliefs (Rogers, 1995; Isham, 2000). Second, social homogeneity increases the level of social interaction (Alesina and La Ferrara, 2000; La Ferrara, 2002) and leads to increased access to social resources such as information (Collier, 1998), informal credit and labour exchange. Alesina and La Ferrara (2000) hypothesized that individuals prefer to interact with others who are similar to themselves in terms of income, race or ethnicity. Using data from US localities and group membership, they found evidence in support of their proposition that individuals' income inequality and ethnic heterogeneity reduce the propensity to participate in social activities. Isham (2000) found evidence that the ethnic homogeneity of social networks in rural Tanzania significantly increased information diffusion and the adoption of fertilizers. On the other hand, social homogeneity of a social network may imply that members also have similar information so that less is gained from exchanging information.

The content of information from the social network also depends on the experience and the skills of the network members (in terms of education and/or whether they are adopters of the technology). Second, as already mentioned, networks exert some social pressure on their members besides informational effects. Networks with some members who have adopted the new technology not only provide accurate information to their members but also persuade them to adopt. Bandiera and Rasul (2002) observed an inverted U-shaped relationship between the number of adopters known by the potential adopter and the adoption of sunflowers as a crop in Northern Mozambique. The authors suggest that the inverse U-shaped relationship may imply two opposing effects. First, they suggest that the inverse relationship may imply the presence of strategic delay of adoption by people who know many adopters, which is consistent with the findings of Katz and Shapiro (1986) and Farrel and Saloner (1985). Bandiera and Rasul (2002) also suspect that there could be other benefits, in addition to information-sharing, that are provided by the social network and that could offer an alternative explanation for the inverse U-shaped relationship between the probability of adoption and the number of known adopters. Accordingly, they propose that further research should investigate the presence of other mechanisms. The present study investigates the possibility of increased access to bilateral transfers as an alternative mechanism through which social networks may influence technology adoption in addition to information diffusion.

4.2.2. Social networks, bilateral transfers and technology adoption

Social networks exist everywhere, but for different reasons. In the rural areas of the developing economies, where credit and insurance markets are scarce and income fluctuations are endemic, social networks are an indispensable part of people's livelihood. Households engage in informal mechanisms such as bilateral transfers to share risk and smoothen their consumption (Fafchamps and Lund, 2003). Bilateral transfers in developing economies take two forms: as assistance in kind (gifting giving, labour exchange, borrowing farm implements, borrowing land for farm production) and informal credit. Both forms of exchange depart from standard credit and insurance contracts in two fundamental ways (Fafchamps, 1999). First there is no explicit link between what is given and the obligation to pay, but the assistance is based on the implicit obligation to reciprocate. "If you help me today, I will help you in the future." Second, the zero-interest informal credit is exchanged between individuals who trust each other. Often the time of repayment is not specified at the time of transaction or can be renegotiated. The key feature of both forms of bilateral transfer is that they are based on personal long-standing relationships and an implicit obligation to reciprocate. The desire to preserve long-standing relationships motivates the reciprocity and acts as a self-enforcing mechanism (Posner, 1980).

How can bilateral transfers influence technology adoption? Bilateral transfers may influence technology adoption decisions in two ways. First, having access to a social network that can help in times of crisis reduces risk aversion and may enable individuals to experiment with new technologies. Second, access to assistance, whether in kind or in the form of informal credit, complements the households' resources, which may increase their economic freedom while making production decisions. This means that the more access there is to bilateral transfers, the greater the economic flexibility and willingness to adopt high-yielding but resource-intensive technologies. Improved banana management technology is resource-using, which means that where an expenditure constraint is binding, it might not be adopted. In addition, the peak labour demands in banana production coincide with the peak labour demand for annual crops. A household that receives cash or in-kind transfers from other households may be able to overcome these constraints and hence implement high-yielding but labour-intensive techniques.

The effect of bilateral transfers from social networks can also be negative. As mentioned in the previous paragraphs, interactions in a social network depend on trust and the ability to reciprocate. In a small village where individuals know each other, a person's failure to reciprocate may result in the loss of a link not only to the giver but to the whole of his social network, because the giver may go around speaking ill of the defaulter, despising and rumour mongering being one of the mechanisms used to reduce opportunism. This means that heavy reliance on bilateral transfers may limit investments in activities that are considered risky, which could limit the adoption of new technologies in agriculture.

4.3. Overview of the literature on the determinants of social capital

There are competing explanations for social capital formation. Some researchers have taken a history-centred approach and explain social capital formation on the basis of historical events. For example, Putnam (1993) reports that social capital is the result of a lengthy historical institutional development that is difficult to build externally. Hyden (2001) posits that the types of social capital that will emerge and the extent to which people will engage in any of them is very much determined by the history of previous efforts to form social capital. "It has to grow organically from the social dynamics that characterize society and hence may not be easy to influence externally" (Hyden, 2001 pp162). However, other researchers take an actor-centred approach and argue that organizational social capital may be eroded by economic restructuring (Heying, 1997) and may also be created within a short time through national organizations (Minkoff, 1997) or community face-to-face interactions (Wood, 1997). Fox (1996) also argues that social capital can be co-produced by the state or by local societal actors and external actors in the society. Glaeser et al. (2001) conceptualises social capital as being the result of investment decisions taken by individuals.

The review of literature in this section is guided by the definition of social capital presented in section 4.1.2. The object is to identify which household and community-level variables should be included in the empirical estimation of determinants of social capital among rural households in Uganda.

As defined in the present study, social capital has two components: institutional social networks (formal) and private (informal) social networks. These components represent stocks of social capital accumulated through individual investment efforts for given household characteristics and a set of exogenous community-level factors. The next section presents a review of the literature on the determinants of participation in institutional social networks (hereafter referred to as associations), followed by a review of the literature on the determinants of participation in private social networks.

4.3.1. Determinants of participation in associations

The existence of associations has been a commonly used indicator for social capital since Putnam's (1993) publication on social capital, though there are many alternative definitions[2]. With the increasing interest in social capital, and specifically in grass-roots associations, shown by many development practitioners the question relevant to policy is what conditions participation. Associations may be formed voluntarily or induced by a third party through coercion. In the present study, the focus is on associations where participation is voluntary and hence the review of literature will be limited to the factors that influence voluntary participation in associations. Both theoretical and empirical factors that influence individual decisions to participate in associations have been proposed.

From the theoretical work, it is indicated that associations will form if a common problem exists and the cost of providing the collective good incurred by each member is lower when provided by a group rather than an individual (Olson, 1965; Cornes and Sanders, 1986). The size and characteristics of the group experiencing a common problem as well as the constraints faced by the individuals interacting are identified as factors that influence the incentives. Olson (1965) argues that since the fraction of the collective good that each individual receives declines as the group's size increases, the incentives should be greater in small groups than in large groups and that this should encourage the formation of smaller-sized associations. In small groups

[2] The fact that the concept of social capital has been defined differently in various disciplines means that the factors that influence its formation will affect the definition of the concept and these factors may differ.

individuals are also able to monitor what others are doing, which is costly in large groups.

The existence of a leader in the group to coordinate its activities, implicitly reducing the cost of monitoring for other members in the group, is also important (Olson, 1965). The author describes this leader as a member of the group with such a large fraction of the total benefit that he would be better off if he/she paid the entire cost alone rather than going without the collective good. From the sociological perspective, Svendsen and Svendsen (2004) also assert that an association will be formed when a leader emerges. Although these authors approached the matter from a different perspective, each recognized the importance of leadership in collective action.

Other theoretical work has identified three factors that intervene in the decision-making process regarding participation in associations. These are trust, cooperation and the direct utility of associations and social networks (Alesina and LaFerrara, 2000; LaFerrara, 2002). "Trust," as described by Dasgupta (2005), is the fundamental problem for people who would like to transact with one another. The type and degree of trust required to facilitate a transaction depend on the personal characteristics of the participants, the institutional environment and the nature of the transaction. When formal institutions are effective in protecting property and contract rights, trust is rapidly established and transactions between people who are less well known to each other are likely (Knack and Keefer, 1997. This type of trust, commonly referred to as "general trust," exists at the community level and facilitates participation in large organizations (LaPorta et al., 2000). General trust arises from general knowledge about the population of agents, the incentives they face and the upbringing they have received (Platteau, 1994; Fox, 1996). On the other hand, when institutions are not effective in protecting contracts and property rights, as is the case among the rural populations of most poor countries, "general trust" takes time and effort to establish, which limits exchanges to people who know each other's reputation. An important implication, which is relevant to the present study, is the fact that associations are likely to be small and formed amongst people who know each other and can easily monitor each other's actions.

In the absence of general trust, personal trust and norms of cooperation act as alternative mechanisms through which exogenous variables may influence participation in associations. Cooperation may prevail among people even at low levels of trust when reputations are known and ample opportunity for future punishment is available (Laporta et al., 2000). In the theory of repeated games, the "folk theorem" establishes that cooperation is sustainable if there is a high probability that interactions will be repeated and players are able to monitor and punish defectors. This implies that people living in a community with low mobility or less probability of moving away from that community will have a greater incentive to cooperate and invest in social capital (Glaeser et al., 2001; DiPasquale and Glaeser, 1999), even when the general level of trust is low. Trust and cooperation are positively correlated but not identical (LaFerrara, 2002).

When the formal institutional environment does not favour the evolution of general trust, the role played by personal trust or norms of cooperation in the formation of associations depends on the nature of the transactions in the associations. Haddad and Maluccio (2003) analysed membership in sensitive (financial) groups and non-sensitive (non-financial) groups in South African communities. They found that trust in neighbours and extended family has a significant impact on membership in the case of financial groups but not necessarily in the case of groups in which exchange interactions are not sensitive (e.g. non-financial). Instead, household-level factors, such as the level of education of the household head, and demographic factors influence participation in non-sensitive groups.

From empirical studies it merges that trust and norms of civic cooperation depend on individual-level characteristics such as education, age and wealth (Haddad and Maluccio, 2003), as well as community-level factors. Among the more important community-level factors are social and economic heterogeneity (Alesina and LaFerrara, 2000; Alesina and LaFerrara, 2002; McCarthy et al., 2004; LaFerrara, 2002), population density (McCarthy et al., 2004) and communication infrastructure. Knack and Keefer (1997) find that trust and norms of civic cooperation are stronger in countries that are less polarized along lines of class or ethnicity. Alesina and La Ferrara (2002) report that individuals in racially mixed communities in the United States have less trust.

Heterogeneity in social norms and preferences may make agreements difficult to achieve (McCarthy et al., 2004), reduce trust among members (Alesina and LaFerrara, 2002) or lower the direct utility of participation (Alesina and LaFerrara, 2000), resulting in low cooperation. Similarly, differences in economic activities give rise to asymmetry in benefits and contributions among different members (La Ferrara, 2002). Each individual puts a different value on the group good, making it difficult to find an association that will satisfy all the various needs or preferences (Olson, 1965). This could limit the rate of participation when only one group is considered (La Ferrara, 2002) or increase the aggregate participation if the population can be stratified into homogenous groups (Cornes and Sandler, 1986).

LaFerrara (2002) argues that membership in a group that provides a shared economic benefit depends on income distribution and the types of access rules involved. Under an open-access rule (i.e. everyone is free to join as long as he/she pays dues), the wealthier households will drop out of the group when inequality increases because their incentive for participation will be lower when the cost of provision is a proportion of individual income. On the other hand, the group composition will be relatively unbalanced in favour of the relatively rich households under restricted-access rules.

Population density is the other community-level variable that has been reported in the literature to be important in regard to cooperation (Alesina and La Ferrara, 2002; La Ferrara, 2002). In this literature, it is argued that the fixed costs of cooperation are high at low population densities. On the other hand, the variable costs of communication and monitoring increase with the population (McCarthy et al., 2004; Olson, 1965). In some cases a high population may give rise to subgroups as a strategy to reduce the costs of monitoring (McCarthy et al., 2004), which may ultimately increase the rate of social participation (La Ferrara, 2002).

The role personal and household characteristics play in social capital formation has also been examined (Haddad and Maluccio, 2003; La Ferrara, 2002; Gleaser et al., 2001). Education is linked to information acquisition, trust formation and the general productivity of social capital. Aside from incentives, participation can also be influenced by time and budget constraints. Participation in associations requires time and sometimes membership fees that may be beyond the means of the households that control fewer resources. In particular, poorer households may have such barriers to participation in associations (Godquin and Quisumbing, 2005).

4.3.2. Determinants of private social networks

Households not only invest in institutional social capital but also in private social networks (dyadic social relationships). In the social capital research undertaken by economists an individual social network is viewed as partly the result of an individual's own efforts and partly a consequence of the social environment (Glaeser et al., 2001; Fafchamps and Minten, 1999). The social environment determines the constraints and opportunities available to the individual, but the decision to join a social network is voluntary and therefore rests with each individual. One's environment influences the action-outcome chosen. In other words, the environment will influence the probability of success, which in turn influences the expected utility from a set of actions available to the individual. Coleman (1988), in his introduction of the concept of social capital into sociology, noted that the trustworthiness of the social environment is central to interpersonal relations.

Gleaser et al. (2001) took a capital accumulation approach and developed a model of social capital formation at the individual level in which individual social capital was defined as social networks and charisma. They found that social capital formation at the individual level could be explained by seven factors: (1) The relationship between social capital and age is first increasing and then decreasing. This is true in the case of other forms of capital accumulation as well. (2) Social capital declines with expected mobility. (3) Social capital investment is higher in occupations involving higher skills. (4) Social capital is higher among homeowners. (5) Social capital falls sharply according to physical distance. (6) People who invest in human capital also invest in social capital. (7) Social capital appears to have interpersonal complementarities.

Taken together, the literature on social capital formation explains how constraints in an individual's environment shape the size and form of social networks that he/she will form. The self re-enforcing nature of social capital is demonstrated. Trust and norms of cooperation, i.e. the cognitive forms of social capital (Upholf, 2000), come out as important mechanisms through which exogenous factors may affect participation in associations and social networks. Because trust among rural populations exists within small, tightly closed social networks, associations (local organizations) are likely to be formed voluntarily among individuals who already have some predetermined relationship, such as relatives or a group of friends, suggesting that there could be some interaction between these two forms of social capital. However, this literature does not examine the interaction between the two forms of social capital.

4.4. Summary

There has been increased interest in the role of informal institutions in the adoption of new technologies in developing economies. This chapter has shed light on different forms of social capital and the channels through which it could influence the management behaviour of small-scale producers in developing economies. Despite conceptual weaknesses, previous studies demonstrate that social capital plays a significant role in agricultural development. Social capital may influence the choice of a technology through social learning and bilateral transfers. The evidence summarized in this chapter also demonstrates that social capital is not uniformly distributed among rural households. Both household and community attributes may contribute to variations in the distribution of social capital.

CHAPTER 5

CONCEPTUAL FRAMEWORK: CHOICE OF A CROP MANAGEMENT TECHNOLOGY IN AN AGRICULTURAL HOUSEHOLD MODEL WITH SOCIAL CAPITAL

This chapter presents a theoretical framework for analysing the choice of a crop management technology by semi-subsistence households. The choice of crop management technology is analysed within an agricultural household framework that integrates production and consumption decisions to address the problem of missing or incomplete markets[1], a common feature in developing economies (Singh et al., 1986; Sadoulet and de Janvry, 1995; de Janvry et al., 1991). In these economies, markets may fail due to a variety of transaction costs, including high transportation costs, the opportunity cost of time involved in selling and buying, and risk associated with uncertain prices and the uncertain biophysical environment (de Janvry et al., 1991; Sadoulet and de Janvry, 1995). In the present study, market failures are assumed to be associated with transaction costs such as high transportation costs in the output markets (Mugisha and Ngambeki; 1994) and incomplete or missing input markets.

In Uganda, across much of the producing region, semi-subsistence households growing bananas have uneven access to markets. Some households participate as sellers, some as buyers only, and nearly a quarter do not participate at all (Edmeades et al., forthcoming). There is also minimal or no participation in the input markets (i.e. labour and organic fertilizers) for banana production, implying that the prices of these inputs are endogenous to the household (determined within the household) (de Janvry et al., 1991). Because virtual prices are determined by equating supply with demand, they depend on all factors that influence household decision making. As a consequence, production and consumption decisions cannot be separated (Strauss, 1986).

When some prices (whether in the output or input markets) faced by the household are endogenous, the profit maximization approach becomes inappropriate for analysing production decisions. Institutional weaknesses in developing economies contribute

[1] A market fails when the cost of a transaction through market exchange creates more disutility than the utility gain that it produces, such that no market transactions occur. Market failure is household-specific (de Janvry et al., 1991).

towards rendering information about new technologies imperfect, adding another source of non-separability of production and consumption to household decision making. Many of the theoretical approaches developed to predict seed and fertilizer adoption during the green revolution were based on profit maximization in the context of risk aversion. In the present study a utility maximization framework induced by market imperfections is assumed to be the objective underlying the household choice of a crop management technology.

Agricultural household framework, induced by market imperfections, has previously been applied to analyse the production behaviour of semi-subsistence households (e.g Edmeades, 2003). The novel insight in the present analysis is the extension of the basic agricultural household model to explicitly incorporate social capital in the modelling framework. Social capital may facilitate access to information about technologies (Isham, 2000; Narayan, 1997; Collliers, 1998) and others resources in form of bilateral transfers that could expand the household resource endowments, which, in turn, may influence production behaviour.

The improved banana production management technology consists of a package of several techniques for managing soil fertility, pest and disease constraints. The soil fertility management techniques include mulching and manure application. The pest and disease management techniques include corm paring, de-suckering, stumping and pseudo-stem management. More details on these techniques are given in Chapter 2. Although it is possible to implement the subcomponents individually, the full benefits of using the improved banana production management technology are achieved when all components are applied simultaneously. The implication of this is that when the subcomponents are many, the technology becomes complex and knowledge-intensive. Farmers may prefer to adopt the components sequentially so as to gain knowledge and/or accumulate capital that will enable them to adopt the whole package in the long run. Formal credit components could be incorporated in the technological package to reduce the expenditure constraint (see Chapter 3 for the review of the adoption literature). However, since participation in the formal credit market by rural households in Uganda is low (Edmeades et al., forthcoming), no attempt is made to model the role of formal credit markets in the choice of management practices by banana farmers.

As stated earlier, unlike the green revolution type technologies, the improved banana production management technology is farmer-made. This means that the management technology is not only knowledge-intensive but is also intensive in the use of local resources such as labour and land. Since banana farmers face some market constraints, informal mechanisms can serve as one of the means of overcoming market constraints. In the present study, the modelling approach emphasizes the mechanisms that allow the incorporation of social capital into the analysis of crop management technology.

Modelling the choice of crop management practices follows a number of steps. The goal is to analyse the effect of market constraints that exclude some households from participation and incorporate social capital into the modelling of crop management decisions. The present work diverges from the previous work related to the role of social capital in technology adoption (e.g Isham, 2000) in two significant ways. First, the optimal adoption decisions in the present analysis are derived from the agricultural household framework. This provides a basis for analysing the effect of market constraints on adoption decisions and the role of social capital in overcoming these constraints. Second, the modelling approach offers two explicit mechanisms (information and bilateral transfers) through which social capital may influence technology adoption.

The static risk-free model with stochastic production and incomplete markets is used to examine the effect of market constraints and illustrate how social capital may influence the production behaviour of agricultural households. The model also analyses the choice of a crop management technology under complete market conditions for the purposes of comparison. Next, uncertainty about the relevance of the technology is introduced to analyse the role of farmers' beliefs about the effects of the existing state of nature on biotic factors in technology adaptation.

5.1. Choice of a crop management technology under incomplete markets

In Uganda bananas are typically produced using family labour and organic fertilizers (used as mulch and manure). Organic fertilizers are mainly produced on the farm as by-products of other farm activities and there is virtually no market for the selling or purchasing of these inputs[2]. Consequently there is no market price for organic fertilizers. Similarly, reliance on family labour in production implies that leisure is valued by its marginal worth to the household rather than as an opportunity cost derived from a market wage rate. Because of this, production and consumption decisions are taken simultaneously (de Janvry et al., 1991), implying that production behaviour cannot be analysed without analysing the consumption side of the model. This section presents each side of the model in turn.

Based on Singh et al's (1986) formulation of the basic agricultural household model, the household derives utility from the consumption of bananas (x^B), other goods (x^G), and home time (h). For the sake of simplicity, it is assumed that other goods are purchased from the market and that home time is simply the time not spent on the production of household income. The household maximizes utility from the consumption of bananas, other goods and home time conditioned by a set of household characteristics (Ω_{HH}).

$$\max_{\psi} u\left[x^B, x^G, h \mid \Omega_{HH}\right] \qquad (1)$$

Included in the vector of the household characteristics are factors that influence the marginal utilities of the consumption items and hence reflect the consumption preferences of the household.

On the production side, the household engages in banana production mainly for home consumption but a surplus may be sold on the market. Variable inputs, mainly labour (L) and organic fertilizers (F), are used to produce banana output (Q^B) on land pre-allocated to the crop ($\overline{A}$) for given farm characteristics (Ω_F) and the stock of knowledge (K). Banana output is assumed to be strictly increasing in variable inputs but at a decreasing rate for a given piece of land allocated to banana production ($\overline{A}$), a vector of exogenous farm characteristics (Ω_F) and the stock of knowledge (K_t).

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[2] Household demand for this type of input is conditional on its own supply.

Bananas can be produced using two alternative management technologies: the improved management technology (f^I) and the traditional management technology (f^T). The improved management technology utilizes labour (L) to implement agronomic practices and techniques for maintaining high sanitation of the banana mat[3] and two types of external organic fertilizers (fertilizers in the form of mulch and manure application), as expressed in the vector (F). Use of the improved management technology increases the productivity of the land allocated to banana, which increases the amount of bananas available for household consumption and the surplus for sale. The yield effects of the improved technology are significantly superior to those of the traditional technology. The improved technology requires additional resources in the form of labour or cash income to hire labour. The farmer incurs some variable costs (in terms of time or money for hiring labour) in the gathering, transportation and application of the organic fertilizers. Banana output under the improved management technology (f^I) may be specified as follows:

$$q^I = f^I(A^I, L, F \mid \Omega_F, K_t) \qquad (2)$$

Following the model of Isham (2000) and Feder and Slade (1984), it is assumed that the stock of knowledge (K_t) evolves as a function of experience over years with the technology (τ), a set of diffusion parameters ($\mathbf{\Omega}_D$) and different forms of social capital (Ω_{SS}). Diffusion parameters include cumulative contact with the extension educators and the level of diffusion of the technology within the community. Some of the forms of social capital that are likely to influence information acquisition and hence knowledge accumulation are discussed in Chapter 3. The stock of knowledge can be expressed as: $K_t = k(\tau, \Omega_D, \Omega_{SS})$. Substituting for K_t in equation (2), and rewriting equation (2) gives:

$$q^I = \left(A^I, L, F \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS})\right) \qquad (3)$$

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[3] A banana mat is a collection of plants that are propagated from the same underground stem, which is commonly described by farmers as plants living as one family with a mother, a daughter and granddaughter.

The traditional management technology uses only labour (L) and land allocated to banana to produce banana output for a given set of farm characteristics (Ω_F). It is assumed that banana output under the traditional technology does not depend on the knowledge stock, since the technology has been available to the communities for many years and all farmers are assumed to have full information about it. Banana output under the traditional management technology is given by the following production function:

$$q^T = f^T\left(A^T, L \mid \Omega_F\right) \tag{4}$$

The two technologies compete for land allocated to banana production ($A^I + A^T = \overline{A}$). The household can choose to manage all its bananas with the improved management technology or with the traditional management technology. The household also has the option to allocate part of the banana area to the improved management technology and the remainder of the banana area to the traditional technology. The share of the banana area the farmer allocates to the improved management technology is represented by (δ) and ranges from 0 to 1. It is equal to 0 when no banana area is allocated to the improved technology (i.e. $A^I = 0$) and equals 1 when the entire banana area is allocated to the improved management technology (i.e. $A^I = \overline{A}$). Given a binding land constraint ($\overline{A}$), the total banana output obtained by the farmer is given by:

$$Q^B = f^I(A^I, L, F \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}) + f^T(\overline{A} - A^I, L \mid \Omega_F) + \varepsilon_i \tag{5}$$

ε_i is a random variable assumed to be normally distributed with the mean at zero and constant variance. The inclusion of the random variable depicts the idea that banana production in any specific period is subject to variations associated with uncertain weather conditions. The specification of the stochastic structure adopted in equation (5) assumes that farmers are risk-neutral with respect to the banana management technologies but face exogenous risk factors associated with the uncertainty of weather conditions. Therefore the choice of the management technology is based on expected output. If we assume that the total banana area is equal to one ($\overline{A} = 1$), then $A^I = \delta$ and equation (5) can be rewritten as:

$$Q^B = f^I(\delta, L, F \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}) + f^T(1-\delta, L \mid \Omega_F) + \varepsilon_i \tag{6}$$

The household faces a number of constraints. The household has an initial endowment of income. In contrast to the standard consumer model assumed under perfect market conditions, in the presence of incomplete markets the income of the household is endogenous at the time of making decisions. The only income the household has at the time of making decisions is in the form of exogenous cash endowments (E). The formulation of the exogenous income in this model departs in some ways from the more typical formulation of the exogenous income in the literature. Here, the household's exogenous income (E) comes in the form of net transfers from private assets (I) or bilateral transfers from social networks (Ω_{SS}). The household may also receive income in the form of bilateral transfers such as gifts, free labour, remittances or informal credit from its social network of friends, relatives or membership in credit associations. This implies that controlling for the exogenous income from private assets, a representative farmer with social capital that can generate significant bilateral transfers will be able to overcome expenditure constraints and adopt a new technology. As discussed in Chapter 1, this possibility has not specifically been considered in the economic modelling of technology adoption. Under this extended set-up, the exogenous income can be expressed as a function of transfers from private assets (I) and social capital (Ω_{SS}) as: $E = e(I, \Omega_{SS})$.

The full income constraint is formulated as the market value of the marketed surplus $P^B(Q^B - x^B)$ plus exogenous income ($e(I, \Omega_{SS})$) and excludes the time endowment because its opportunity cost is endogenous. The household income is spent on purchasing other goods (x^G) consumed by the household at market prices (P^G).

$$P_i(Q^B - x^B) + e(I, \Omega_{SS}) - P^G x^G = 0 \tag{7}$$

Both input and output markets for bananas are often incomplete or not readily available in rural areas. Market constraints on household production can be expressed as a function of exogenous characteristics (Ω_M) such as farm and market characteristics. The specific farm and market characteristics influence the magnitude of the transaction costs involved in market exchange and, through the shadow price, the household's choices. The fixed supply of organic fertilizer highlights the missing markets for these inputs and also defines the linkage between the choice of banana management technology and other farm activities, farm resources and household characteristics. The household cannot demand more fertilizer than it can supply from its own sources: $F^{DD} \leq F^{SS}$. This inequality reflects the fact that supply is fixed at the time of making decisions and that demand depends on supply[4]. Since organic fertilizers are produced as by-products of other activities on the farm, their supply depends on whether those activities are undertaken. Factors such as landholding and labour that influence those activities (i.e. the cultivation of annual crops) and/or livestock capital endowments will influence the costs of organic fertilizers to the household and, as a consequence, the choice of management techniques.

Imperfections in the labour market depicted by an explicit lack of wage labour imply that household participation in the labour market is conditional on the magnitude of the transaction costs involved. Some households may participate and others may not. Each household has an initial endowment of time it can allocate between banana production and leisure $T = L + h$. The production technology is a physical relationship defining the set of inputs used in banana production and generated output as specified in equation (6).

In summary, the household's maximization problem can be expressed as follows:

$$\max_{\psi} u\left[x^B, x^G, h \mid \Omega_{HH}\right]$$

$$\psi = (x^B, x^G, h, L, F, \delta)$$

[4] Although organic fertilizers are produced as by-products of other farm activities, at the time of making the choice of the preferred banana management technology, the supply of organic fertilizers is fixed.

Subject to:

Full income constraint: $P^B(Q^B - x^B) + e(I, \Omega_{SS}) - P^G x^G = 0$

Time constraint: $T = L + h$

Production technology: $G\left[f^I(\delta, F, L \mid \Omega_F k(\tau, \Omega_D, \Omega_{SS}) + f^T((1-\delta), L \mid \Omega_F) + \varepsilon_i\right]$

Non-tradable constraint: $F^{SS} \geq F^{DD}$

Non-negativity restriction: $F \;, \delta, L \geq 0$

The first-order necessary conditions are derived based on the assumption that an interior solution will hold for some choices but not for others (corner solutions). For example, it is assumed that every household will consume bananas, other goods and leisure time, and hence an interior solution is expected on the consumption side. However, the utility derived from the use of the management technology may vary among households and the corner solution is possible for some households. Kuhn-Tucker conditions are used to derive optimal choices of crop management technology.

First-order condition

x^B: $$\frac{\partial U(.)}{\partial x^B} - o P^B = 0 \tag{8}$$

x^G: $$\frac{\partial U(.)}{\partial x^G} - o P^G = 0 \tag{9}$$

h: $$\frac{\partial U(.)}{\partial h} - \vartheta = 0 \tag{10}$$

L: $$\varphi \frac{\partial G(.)}{\partial L} - \vartheta = 0 \tag{11}$$

F: $$\varphi \frac{\partial G(.)}{\partial f^I} \frac{\partial f^I}{\partial F} - \iota \leq 0 ; \qquad F \geq 0 \tag{12}$$

δ: $$\varphi \left(\frac{\partial G(.)}{\partial f^I} \frac{\partial f^I}{\partial \delta} - \frac{\partial G(.)}{\partial f^T} \frac{\partial f^T}{\partial \delta} \right) \leq 0 ; \; \delta \geq 0 \tag{13}$$

o: $$P_i(Q^B - x^B) + e(I, \Omega_{SS}) - P^G x^G = 0 \tag{14}$$

ϑ: $$T = L + h \tag{15}$$

ι: $$F^{SS} \geq F^{DD} \tag{16}$$

$$\varphi: \qquad G\left[f^{I}(\delta, F \mid \Omega_F k(\tau, \Omega_D, \Omega_{SS}) + f^{T}(1-\delta,); L \mid \Omega_F\right] \qquad (17)$$

$o, \vartheta, \iota, \varphi$ are respective multipliers for the full income constraints, the time constraint, and non-tradable and production technology. Equations 10 and 11 reveal a possible solution regarding the choice of labour allocation by the household. Dividing equation (11) by equation (10) gives the marginal rate of substitution between work and leisure:

$$MRS_{L,h} = \frac{\partial G(.)}{\partial L} \Big/ \frac{\partial U(.)}{\partial h} = \frac{1}{\varphi} = w^{*} \qquad (18)$$

The household equates the rate of technical substitution of labour used in banana production for leisure (given as a ratio of the physical marginal productivity of labour to the marginal utility of leisure) with the marginal valuation of labour, $(\frac{1}{\varphi})$ which is equal to the shadow price (w^{*}) of labour. The shadow price of labour depends on all the exogenous variables in the utility function as well as on production technology, the market wage rate (w) for unskilled labour and other market characteristics (Ω_M) that motivate the household to be self-sufficient in its labour supply. The shadow price is the opportunity cost of leisure forgone by transferring time to banana production and can be expressed as a function of market characteristics (Ω_M); household consumption characteristics (Ω_{HH}) that influence the marginal utility of leisure; the knowledge stock ($k(\tau, \Omega_D, \Omega_{SS})$; exogenous income ($e(I, \Omega_{ss})$); and farm characteristics (Ω_F) as follows:

$$w^{*} = w(w, \Omega_M, \Omega_{HH}, k(\tau, \Omega_D, \Omega_{SS}); e(I, \Omega_{SS}); \Omega_F) \qquad (19)$$

The solution of the optimisation problem expressed in equations (12) and (13) consists of two related decisions: the decision regarding whether or not to use improved management technology and the decision regarding land allocation to the improved management technology, given that the optimal solution in equation (12) holds with equality. When the optimal solution in equation (12) holds with equality, then the input (F) will be used and the household will equate the marginal valuation of the input to production to its shadow price. However, if the optimal solution holds with inequality, the first order condition can also be expressed as follows:

$$\frac{\partial G(.)}{\partial f^{I}}\frac{\partial f^{I}}{\partial F} < \frac{\iota}{\varphi} = P^{*} ; \qquad F = 0 \tag{20}$$

In other words, the household will be unwilling to use the input (F) if its shadow price is greater than its marginal valuation (in terms of its marginal physical productivity). In this case, the observed demand of the input (F) will be censored at zero. The shadow price of the input (F) depends on the market characteristics that constrain transactions, household characteristics, farm characteristics that determine the supply and productivity of the input, knowledge parameters and all other factors that influence the productivity of the input in banana production.

$$P^{*} = F(\Omega_{M}, \Omega_{HH}, k(\tau, \Omega_{D}, \Omega_{SS}); e(I, \Omega_{SS}); \Omega_{F}) \tag{21}$$

The optimal solution in equation (13) is conditional on the optimal solution in equation (12), thus revealing the simultaneity of the two decisions. The optimal solution in (13) holds with inequality when the optimal solution in equation (12) also holds with inequality and no land is devoted to the improved management technology, implying that the expected gain from banana production when all land is used according to the traditional management technology exceeds the expected gain when some improved management technology is applied.

$$E\left((P^{B} f^{T}\right) > E\left(P^{B} f^{I} + P^{B} f^{T}) - P^{*} F\right) \tag{22}$$

Note that the shadow price " P^{*} " of the input (F) is now a parameter determined in the first adoption decision (discrete choice). It defines the linkage between the land share allocation to the improved management technology and the market characteristics. The price of banana (P^{B}) may be exogenous for households that participate in the market and endogenous for households that do not participate in the market, further linking the optimal utilization of land under the improved crop management technology to market characteristics and household consumption preferences.

When the improved management technology is applied, the conditions in (12) and (13) hold with equality and the optimal land share allocated to the improved management technology is determined by equating the marginal net benefit in both management technologies.

$$E\left(P^B(f^I - f^T) - P^*\right) = 0 \tag{23}$$

Based on the first-order conditions, the following demand equations can be derived for the improved input (F) and land share allocation (δ) to the improved management technology:

$$\begin{aligned} F^* &= F(P^*, P^B, w^* \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS})) \\ \delta^* \mid F > 0 &= A(P^*, P^B, w^* \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS})) \end{aligned} \tag{24}$$

Substituting for the endogenous prices expressed in equations (19) and (21) gives the optimal decision as to whether or not to use the improved organic fertilizers and the conditional demand for the improved banana management technology (expressed as the land share allocated to the technology) reduced form. Demand for sanitation practices can be derived in a similar way.

$$\begin{aligned} F^* &= F(, P^B, w, \Omega_{HH}, \Omega_M, \Omega_F, e(I, \Omega_{SS}); k(\tau, \Omega_D, \Omega_{SS})) \\ \delta^* \mid F > 0 &= F(, P^B, w, \Omega_{HH}, \Omega_M, \Omega_F, e(I, \Omega_{SS}); k(\tau, \Omega_D, \Omega_{SS})) \end{aligned} \tag{25}$$

5.2. Choice of a crop management technology when markets are complete

In this section the model assumes complete markets for inputs and outputs. The purpose of reviewing this special case is to illustrate the biases that would occur in estimating crop management behaviour using profit maximization if producers were constrained by market imperfections.

The assumption of perfect market conditions implies that the markets for all goods exist, that all factor markets are functional and that they involve no transaction costs, risk or uncertainty that could potentially constrain market exchange. All prices, including that of banana (P^B), organic fertilizers (P^F) and the wage rate for labour (w), are exogenous to the household. The household does not have to worry about consumption when making production decisions since the household can now sell what it produces and purchase all it requires from the market at a price equal to the sale price if it produced the goods. The household production behaviour is modelled on that of a firm. The household makes production decisions to maximize revenue.

Since profit is the only income that results from household production choices, maximizing household revenue is equivalent to maximizing profits. The household problem is solved sequentially. Production decisions are taken to maximize profits and the profits earned are used to finance the household consumption demand. The household chooses a production management technology to maximize profits from banana subject to the land allocation constraint. Since profits depend on the banana output, factors such as farm characteristics and the knowledge stock, which influence the productivity of the land allocated to banana, indirectly influence the profitability of bananas. This means that social capital, through its influence on knowledge accumulation, still plays a role in production decisions even when markets for inputs and outputs are perfect.

$$\max \pi(P^B, P^F, w, Q^B \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}) = P^B Q^B - C(P^F, w, Q^B \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS})$$

Subject to

Land allocation constraint: $A^I \leq \overline{A} \qquad \Rightarrow \delta \leq 1$

The demand for the improved management technology, expressed in the form of the demand for organic fertilizers and labour, can be derived from the maximization of the above constrained profit function. The following reduced form equations result:

Supply function for bananas: $Q^* = Q(P^B, P^F, w \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}))$

Demand for organic fertilizers: $F^* = F(P^B, P^F, w \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}))$

Area share:	$\delta^{*} = \delta(P^{B}, P^{F}, w \mid \Omega_{F}, k(\tau, \Omega_{D}, \Omega_{SS})$
Demand for labour:	$L^{*} = L(P^{B}, P^{F}, w \mid \Omega_{F}, k(\tau, \Omega_{D}, \Omega_{SS}))$
Maximum profits	$\pi^{*} = \pi(P^{B}, P^{F}, w \mid \Omega_{F}, k(\tau, \Omega_{D}, \Omega_{SS}))$

On the consumption side, the household maximizes utility specified in equation (1) subject to the budget constraint, which is the sum of the earned profits (π) and the exogenous income (E).

Utility function:	$\max_{\psi} u\left[x^{B}, x^{G}, h \mid \Omega_{HH}\right]$
	Subject to:
Full income constraint:	$\pi^{*} + wT$
Time constraint:	$T = L + h$

The maximization solution yields reduced demand equations for banana, other goods and home time. In the special case of perfect markets, the demand for improved management technology given by: $\delta^{*} = \delta(P^{B}, P^{F}, w \mid \Omega_{F}, k(\tau, \Omega_{D}, \Omega_{SS})$, is nested in the general agricultural household model, the difference being that, since all prices are exogenous, household consumption/worker characteristics are irrelevant in the technology demand equations. However, if these household characteristics are significant, then the use of a profit maximization approach as a framework for analysing adoption behaviour results in an omitted variable bias.

Adoption of the improved banana production management technology will depend on how the market prices of the organic fertilizers affect the profitability of banana production under the improved management technology. Since yield effects are superior under the improved management technology compared to the traditional management technology, a profit-maximizing producer would be expected to allocate all land to the improved management technology if it is profitable to do so or to the traditional management technology if traditional banana production is more profitable. Note that risk neutrality is assumed here. The case of partial adoption does not apply. However, this is not the case observed among banana producers, suggesting that profit maximization may not be the underlying objective of the observed adoption behaviour.

5.3. Choice of a crop management technology under technology relevance uncertainty

The role of uncertainty in technology adoption is well documented in the literature (Feder et al., 1985; Feder and Umali, 1993). There are various sources of uncertainty that can affect the adoption of new technologies, some of which concern the performance of the technology itself, such as yields (output) or price. Potential adopters may also be uncertain about the relevance or fit of the technology in their circumstances. Unlike performance uncertainty, where the decision maker does not know the production function of the new technology with certainty, under relevance uncertainty the decision maker knows with certainty that the new technology is superior to the old technology but does not know with certainty whether the technology is relevant to his/her circumstances. In other words, the uncertainty originates from variability in the state of nature rather than the production function of the technology. The present study focuses on the uncertainty about the relevance of the technology.

Assume that there are two states of nature, namely the occurrence of risk and non-occurrence. Also assume that this type of risk in banana production originates from the biotic and/or abiotic factors, including soil fertility deterioration, pests and diseases, which cause significant yield loss (Gold et al., 1999). Other sources of risk, such as weather variability and price variability, are assumed to be absent for the sake of simplicity and easy exposition[5]. Therefore it is assumed that when pests and diseases are absent and soils are good, banana yields are certain.

Denote as θ_1 the state of nature characterized by biotic and abiotic factors (absence of pests, diseases and soil fertility problems) and θ_2 the state of nature free of these biotic and abiotic factors. The farmer is uncertain about the occurrence of each state

[5] Even if the assumption of uncertainty as to the weather conditions is maintained as specified in section 5.2, it will not affect the results, since it has been assumed to affect banana output under both technologies equally.

of nature but has a belief (η) that the state of nature (θ_1) will prevail and $(1-\eta)$ belief that the state of nature will be θ_2 instead. The farmer's belief is based on his experience regarding the occurrence of each state of nature. If the farmer has no experience regarding the occurrence of these biotic/abiotic factors, he is certain that the state of nature will be θ_2.

Suppose that there are two management technologies for producing banana, namely the improved and the traditional management technologies. The two management technologies are as defined in section 5.1. The farmer is certain that the improved management technology (f^I) is superior to the traditional management technology (f^T) when the state of nature is θ_1. In other words, conditional on the occurrence of biotic factors, banana yields are higher under the improved management technology than under the traditional management technology. That is $(f^I - f^T) > 0 \mid \theta_1$; but the yield gain from the improved management technology is indeterminate under the state of nature (θ_2). The yield gains can be zero, given the fixed genetic yield potential of the crop. The expected net benefit from using the improved management technology is given by:

$$E(b) = P^B(\eta(f^I - f^T) + (1-\eta)(f^I - f^T) - M^*\delta \qquad (26)$$

where "*b*" represents the net benefit from the improved management technology and "M^*" is the vector of the shadow prices of the inputs (representing labour and organic fertilizers) used to implement the improved management technology. If we assume that there is a one-to-one correspondence between land allocated to the improved management technology and the amount of the improved input used, then "M^*" can also be interpreted as the per acre cost of the improved management technology. Suppose that the yield gain from the improved management technology in the absence of biotic and abiotic factors is zero[6] such that $(f^I - f^T) = 0 \mid \theta_2$; then the net benefit from the improved management technology may be expressed as:

[6] This assumption is considered realistic since the improved technology was recommended as mitigating the effects of the biotic and abiotic factors, and taking into account the fixed factor associated with the yield potential of the crop.

$$E(b) = P^B \eta (f^I - f^T) - M^* \delta \tag{27}$$

The farmer's problem is to maximize the net benefit from the improved management technology. The farmer's maximization problem under this type of uncertainty is analysed in terms of the agricultural household framework. Hence the assumption of incomplete markets is maintained. The consumption and production structures are as specified for the case of incomplete markets under certainty, but the difference here is that under relevance uncertainty, stochastic production is not independent of technology. The problem facing the farmer is to choose the amount of the improved inputs, i.e. implicitly the land share allocated to the improved management technology, so as to maximize the expected net benefit of improved management technology.

A Kuhn-Tucker formulation of the maximization is used to derive the optimal decision to allocate a proportion of banana area to the improved management technology:

$$\delta^* : \qquad P^B \eta \frac{\partial E(b)}{\partial f^I} \frac{\partial f^I}{\partial \delta} - M^* \leq 0 \qquad \Rightarrow \qquad P^B \frac{\partial E(b)}{\partial f^I} \frac{\partial f^I}{\partial \delta} \geq \frac{M^*}{\eta} \tag{28}$$

The optimal solution in equation (28) shows that for the improved management technology to be adopted under uncertain conditions with respect to the technology relevance to the farmer's local conditions, the expected benefit from the technology should be greater than or equal to its cost, weighted by the probability that biotic and /or abiotic factors (pests/diseases and soil fertility decline), are present.

The farmer's belief about the occurrence of the biotic/abiotic factors depends on the biotic and abiotic risk (Ω_R) in the community, household characteristics (Ω_{HH}), farm characteristics (Ω_F) and the stock of knowledge [$k(.)$], as follows:

$$\eta = \eta(\Omega_{HH}, \Omega_F, \Omega_R; k(\tau, \Omega_D, \Omega_{SS}) . \qquad (29)$$

From the optimal solution it can be seen that the decision and extent of adoption are a function of the exogenous factors expressed in equation (25) and the farmer's beliefs about the state of nature expressed in equation (29). Incorporating the farmer's belief in the adoption reduced-form equations yields the following reduced equations for the demand for the improved management technology in terms of discrete and continuous adoption decisions under incomplete markets with uncertainty.

$$F^* = F(P^B, w, \Omega_{HH}, \Omega_M, \Omega_F, e(I, \Omega_{SS}); k(\tau, \Omega_D, \Omega_{SS}); \eta(\Omega_{HH}, \Omega_F, \Omega_R; k(\tau, \Omega_D, \Omega_{SS}))$$

$$\delta^* \mid F^* > 0 = \delta(P^B, w, \Omega_{HH}, \Omega_M, \Omega_F, e(I, \Omega_{SS}); k(\tau, \Omega_D, \Omega_{SS}); \eta(\Omega_{HH}, \Omega_F, \Omega_R; k(\tau, \Omega_D, \Omega_{SS})) \qquad (30)$$

5.4. A summary of the household choice of a crop management technology

The foregoing sections presented a mathematical model illustrating the main factors that motivate households to use banana production management practices. In this section, the model is simplified into a schematic diagram to make it attractive to readers less interested in mathematical models. The adoption and use of banana management practices is conceptualised as the decision-making process portrayed in Figure 4.

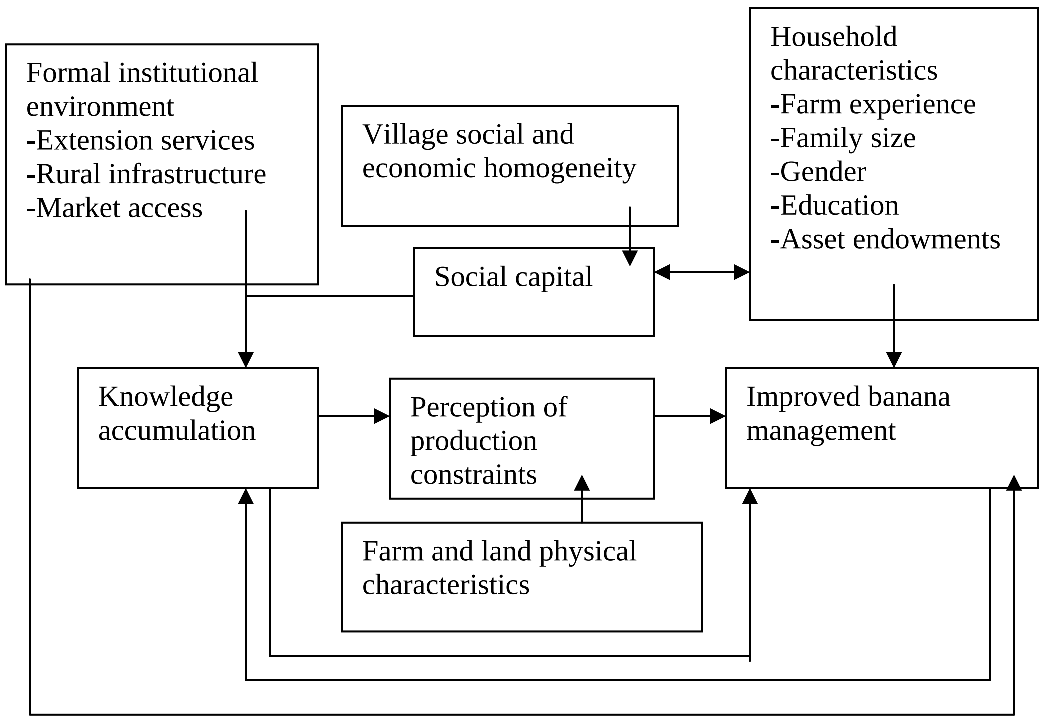

Figure 4. A socio-economic model of the decision-making process for the use of improved banana management practices

The model illustrates that the decision-making process regarding the use of banana management practices has three components: knowledge accumulation, perception formation and the use of banana management practices.

Perceptions may result from physical changes in the environment and/or information accumulation that creates awareness. On the other hand, knowledge accumulation depends on household characteristics and formal and informal information diffusion parameters. Formal diffusion mechanisms include extension and other information dissemination mechanisms. Experience with the technology and social capital constitute the informal mechanisms of information diffusion. Knowledge accumulation involves the acquisition of information about the problem as well as information on the management practices themselves. Hence it has a direct and indirect effect on the use of improved banana production management technology.

Once the problem is perceived and information is acquired, the decision maker decides whether or not to use the management practice and the extent to which it should be used. Although presented in linear form, the process may be non-linear. Perception of the problem may stimulate a search for more information and a decision to use the practice.

Variables cast on the right hand side of equation (30) are modelled to play separate roles in crop management decisions (Figure 4). Social capital influences households' decision to use the improved banana management practices indirectly by influencing knowledge accumulation and through its effect on household characteristics such as asset endowments. The improved banana management technology is resource-intensive and access to social resources such as bilateral transfers and information may influence its use.

The model also shows that social capital depends on factors that may influence the use of a technology directly or through other mechanisms, thus highlighting the complexity of the decision-making processes of agricultural households faced with imperfect market conditions. This means that ignoring the role of social capital may bias the direct effect of these factors on the use of banana management practices. While social capital indirectly influences a household's choice of banana management practices, it is also influenced by other household characteristics and community-level variables (Figure 4). Factors that influence household social capital were discussed in Chapter 4 and the topic will be further discussed in Chapter 8.

5.5. Concluding remarks

This chapter has demonstrated that social capital may influence the choice of a crop management technology through information acquisition and bilateral transfers. The choice of improved banana management practices is described within the framework of an agricultural household model with profit maximization and technology relevance uncertainties as special cases. Variables identified through different special cases and the general model are brought together in a summary and their interaction with the crop management decision-making process is illustrated using a schematic model.

CHAPTER 6
DATA SOURCES AND SAMPLE CHARACTERISTICS

Formal estimation of the models developed in Chapter 5 requires data on improved banana production management technology adoption, farm characteristics, a set of household characteristics, farm and market characteristics, social capital and other village-level factors. This chapter describes the sources of the data used in the empirical estimation, sampling procedures and methods of collecting data. A few basic characteristics of the sample are also summarized.

6.1. Data sources

The data used in the analysis come from two household surveys conducted in Uganda between 2003 and 2004. First, a survey was conducted among 800 households in 40 villages across the major banana-growing areas of the Lake Victoria region of Uganda and Tanzania[1]. Of these, 547 households are located in 27 villages in Uganda. This survey collected detailed information on household characteristics, market factors, landholdings and farm physical characteristics.

A second survey was conducted during the same period among 400 households to gather additional data required for the present study. Three hundred of the surveyed households were among the households selected for the first survey and 100 households were randomly selected from a domain defined by a project entitled "Reviving Bananas in the Central Region," implemented by NARO, the National Banana Research Programme. The 100 households had been surveyed in 2001 to collect baseline information for the same project.

The second survey collected data on social capital, the adoption of improved banana management practices and village-level social characteristics. The survey could not cover the entire household sample selected for the first survey because of budget constraints. Since the second survey was implemented as a sub-sample of the first

[1] The survey was conducted by the National Banana Research Program jointly with the Maruku Research Institution and in collaboration with the International Food Research Policy Institute (IFPRI) and the International Network for Banana and Plantains (INIBAP), as a baseline for the assessment of the socio-economic impact of banana improvement in East Africa. The study was also implemented in Tanzania.

survey, the next section will present a summary of the sampling frame used in the first survey. Following this, the sampling methods used to select the sub-sample and methods of data collection are presented.

6.2. Sampling frame

The domain was purposively selected to cover areas specializing in banana production, including those with declining, increasing and intermediate current levels of production. These correspond roughly to the Eastern, Central and south-western geographical zones in Uganda. The domain was stratified based on elevation (a physical environmental characteristic) and exposure to recently introduced new banana varieties (an institutional characteristic). Elevation is correlated with numerous factors that affect the incidence and severity of most pests and diseases affecting bananas in the Lake Victoria region (Speijer et al., 1994). Elevation is also related to soil quality, climate and the surrounding vegetation in these environments (Tushemereirwe et al., 2001). Two strata were delineated, defining low elevation as being below and high elevation as being above 1,200 masl (metres above sea level).

The domain was also stratified according to the previous exposure[2] to new banana varieties (exposed/not exposed) so as to compare the "factual" (i.e. the actual case) with the "counterfactual" (i.e. the situation in a comparable case where no adoption had occurred). Although the adoption of new banana varieties is not the major focus of the present study, exposure as a stratification variable is relevant to the study since improved banana management practices might have been disseminated along with the new banana varieties.

Geo-referenced data on banana production systems, a digital elevation model, maps of administrative units and information concerning the previous diffusion of banana planting material were used to disaggregate the domain into a total of four strata: (1) low elevation, with exposure; (2) low elevation, without exposure; (3) high elevation, with exposure, and (4) high elevation, without exposure. The domain and four strata

[2] Areas of "exposure" were defined as LC3s where researchers, extension services or other programmes had introduced improved plant material (in the form of banana suckers) into at least one community. Areas with no exposure are those where no organized programme designed to diffuse improved planting material had been conducted, according to personal consultation with NARO.

were then mapped onto the administrative level of a Ward in Tanzania and an LC3 (local council level 3, or sub-county) in Uganda. Wards and LC3s were designated as high or low-elevation based on a simple majority proportion of the unit being above or below 1200 metres above sea level.

An efficient allocation of sample to strata in formal sampling schemes is one that minimizes variation within the stratum and maximizes variation between the strata, in turn minimizing the overall sampling error (Hansen et al., 1953). When the variances in population parameters are known, the sample can be allocated optimally within and among primary sampling units (PSUs) by choosing their number and the number of households per PSU to minimize the survey (sampling and non-sampling) error, given a fixed budget (De Groote, 1996). In this case, the variances in the multiple population parameters of research interest were unknown.

The minimum sample size for conducting hypothesis tests on variables measured at the community level (such as social capital and some physical capital) is 20 each in exposed and non-exposed areas (corresponding to a student's *t*-test). Although a larger sample of communities would have been preferred for the sake of statistical precision, the cost of conducting the research in more than 40 communities scattered across the domain exceeded the budget. The total number of PSUs was therefore fixed at 40, with half distributed through exposed areas and the other half through non-exposed areas. The 40 primary sampling units were then allocated between the two elevation levels and the two countries proportionate to the probability of selection. PSUs were drawn using systematic random sampling from a list frame with a random start. The sampling fractions for the primary sampling units among the four strata in the domain are shown in Table 4.

Table 4. Sampling fractions for primary sampling units (PSUs) in the survey domain

Population of PSUs				Sample of PSUs			
	Elevation				Elevation		
	Low	High	Total		Low	High	Total
Exposed	49	5	54	Exposed	18	2	20
Row pct	(91%)	(9%)	(100%)	s.f.	0.367	0.40	0.37
Non-exposed	155	49	204	Non-Exposed	15	5	20
Row pct	(76%)	(24%)	(100%)	s.f	0.097	0.10	0.098
Total	204	54	258	Total	32	8	40

Source: Smale et al. (Forthcoming)

S.f=PSU sampling fraction (n*ij*/N*ij*), where *i*=elevation (1,2) and *j*=exposure (1,0)
PSU sampling fractions (*s.f.*) vary by stratum, and are defined as the ratio of stratum-specific sample size (n_{ij}) and stratum-specific population size (N_{ij}), expressed as (n_{ij}/N_{ij}). The final sample for Uganda consists of 27 PSUs, of which 18 are located in non-exposed and 9 in exposed areas (Table 5).

Table 5. Survey sites (primary sampling units) as represented by elevation and diffusion status in Uganda

Low Elevation areas		High elevation areas		Total
Non-exposed	Exposed	Non-exposed	Exposed	
14	8	4	1	27

The spatial representation of the primary sampling units is shown in Figure 5 with sampled sites highlighted. Figure 6 shows only the sites surveyed.

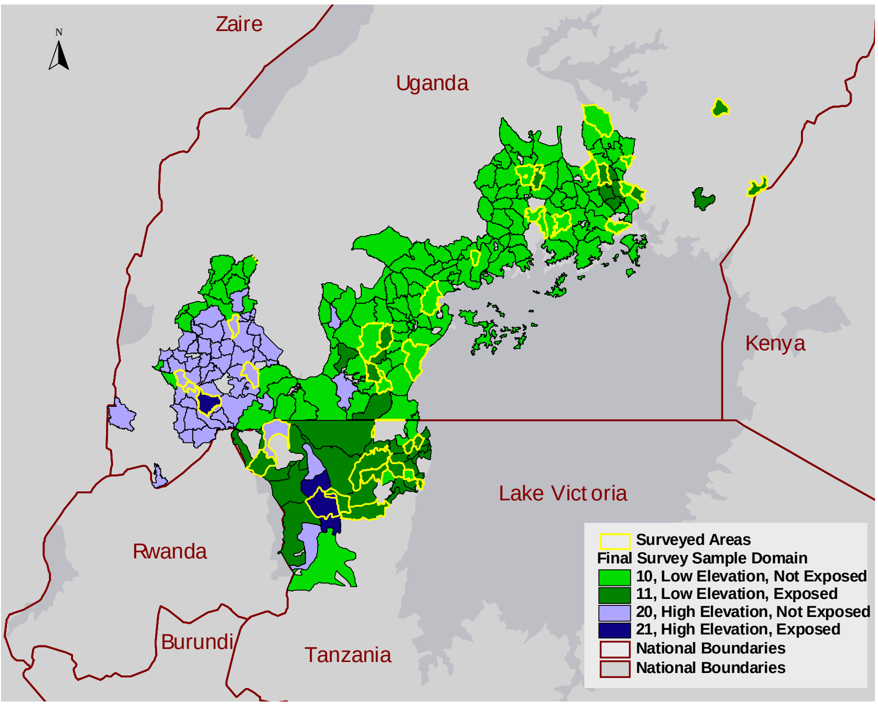

Figure 5. Sample Domain: elevation overlaid with exposure/non-exposure (Smale et al., Forthcoming)

The secondary sampling unit was a village. In Uganda, in each LC3, there are several parishes (LC2s), and each parish consists of several villages (LC1s). One SSU was selected per PSU. The probability of selection (or sampling fraction) of an SSU varies by PSU and is denoted as ($1/M_p$), where M_p represents the number of villages in the p-th PSU (p = 1, …, 40 PSUs in the sample). For most exposed LC3s in Uganda, there is only one exposed LC1 per PSU. Where there is more than one exposed village per PSU, the SSU was drawn with a random number from the list of those villages with over 100 households according to the 1991 census. Whether or not a community selected in the sample had been properly classified as exposed or non-exposed was then verified at the site.

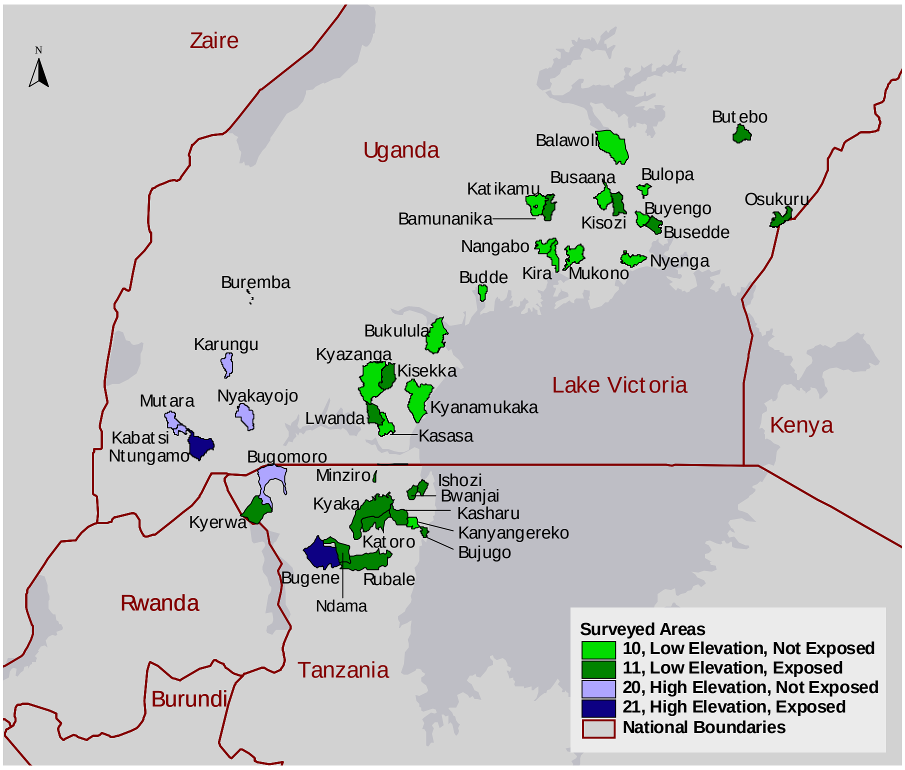

Figure 6. Sites sampled for the first survey (Smale et al., Forthcoming)

The sampled villages were visited and a current list of households in each village was requested from the chairman of the village (LC1). The total number of households selected per village was 20. The probability of selection (or a sampling fraction) of a household varies by village and is denoted as ($20/H_s$), where H_s is the number of households in the s-th village (s = 1 to 40 SSUs in the sample). If there was an order in the list of households, random numbers were used for selection. Otherwise, a random start with systematic random sampling from the list was employed.

The overall probability of selecting a household in the sub-sample (denoted as PSH) is a unique number, and it is defined as the product of the sampling fractions at each level. PSH = $[(n_i/N_i)x(1/M_p)x(20/H_s)]$. For descriptive analysis, survey weights (w) for each household were computed as the inverse PSH.

6.3. Selection of the sub-samples for the present study

The study was conducted in 20 villages selected from the Central, Eastern and Western regions. These regions were selected purposively because they represent major banana growing areas in Uganda and yet differ in their cultural dynamics and social context. This was intended to increase the variation in both the adoption of banana management practices and the social capital variables measured at the village level. The sample selected for the first survey was stratified according to region. Five villages were randomly selected from each region. Five villages were also randomly selected from a domain defined by a project entitled "Reviving banana productivity in central Uganda through introducing improved banana management technologies" implemented by NARO.

In each selected village, 20 households participating in the ongoing research projects were interviewed. The basic unit of observation for the sample survey is the farm household. A farm household is defined according to the culture of which the household is a part, and includes female-headed and child-headed (orphaned) households, as well as male-headed households with more than one wife.

6.4. Data collection methods

Data were collected by face-to-face interviews with the primary decision makers and their spouses using pre-tested questionnaires, complemented by interviews with key informants and actual observations where necessary. The questionnaires were pre-tested on at least 20 households selected from different locations across the three regions. Twenty enumerators were selected and trained in data collection, the importance of the study and data quality management. They were regularly supervised to minimize measurement errors. Survey instruments used to collect data used in the present study are summarized below.

A set of ten structured, pre-tested questionnaires (schedules) were used as instruments for data collection, and each questionnaire was designed to address a different aspect of the study. Six of the instruments were designed and implemented in the first survey. They collected data on household characteristics, farm characteristics, banana plot characteristics and market characteristics. Four were designed and implemented in the second survey. These included banana management schedules, associations and social networks. The format and structure of the banana management and social capital instruments depart in some ways from the more typical household and plot surveys often conducted in studies of technology use by smallholder farmers. These instruments are described briefly below.

Banana management schedules

The banana management schedules elicited information on the farmers' management of the natural resources on their banana plantations as well as sanitation practices (mat management) for pest and disease control, including the use and awareness of recommended practices, and sources of information by management practice. The extent of use of the organic fertilizers for a single production cycle (January to December 2003) was measured by counting the number of mats under each type of organic fertilizer. To minimize measurement errors, the interview was conducted on the plot and the farmer showed the enumerator the parts of the plantation that had been treated with the organic fertilizers as the enumerator counted mats in the area.

For mat management practices, coloured photographs were used to enhance the farmer's recognition of the practice. This helped to overcome the problem of the different names used by farmers and reduced confusion. The use of mat management technologies that could be measured as a continuous variable, such as stumping and pseudo-stem management, was measured by counting the residues that were managed and those that were not managed. The counting was conducted at the end of the production cycle so that the measurement captures the cumulative use of the technique over a period of a year. The idea was that if the farmer used these techniques extensively, unmanaged residues would not be found at the time of counting. In the few cases where neither managed nor unmanaged residues were found[3], the enumerator identified the cause from interviewing the farmer and the observation was excluded from the analysis.

Social capital schedules

Social capital data were collected through discussions with key informants and the sampled households. Key informants (the local leaders and village elders) were interviewed about village social homogeneity (in terms of ethnicity and religious affiliation), and formal and informal organizations. Information generated through key informants helped in identifying social structures and improving the formal questionnaires.

The schedule regarding associations recorded information about household membership, the level of household participation, the major activities of associations, the benefits to the members, as well as the composition, function and leadership quality of associations. These were measured following the work of Narayan (1997). The social network schedule elicited information on the household social network, recorded information on bilateral transfers disaggregated by type of item (specified as labour, cash, food and other durable goods), the relationship between the receiver and the giver and the number of people for each item received or given. To keep the interviews confidential and encourage a high level of cooperation by the respondents, no mention of names was required. The social network schedule also elicited information on the characteristics of social network members (education, ethnicity, religion and location of residence), the major economic activities of the individuals in the social network and the intensity of social interactions and places where interactions often took place.

6.5. Basic characteristics of the sample

Household-selected demographic and socio-economic characteristics of interest are summarized in Table 6. The demographic characteristics (age, gender and education) described are those of the primary banana production decision maker. This could be the household head or another household member. Although sometimes the primary

[3] Banana pseudo-stems may be missing when they have been fed to livestock or used for vanilla or split to make mats for domestic use. However, cases of missing pseudo-stems (managed and unmanaged) were too rare to cause any selection bias in the data.

production decision maker is taken to be the household head, this measure was considered unrealistic for banana producers, given that in some locations banana is predominantly managed by women (the spouses) while the husbands (the household heads) play a minor role. During the survey, the enumerator first identified the primary production decision maker, who then became the primary respondent. The age of the primary decision maker is lower in the higher elevation areas, although this difference is not meaningful. The size of the household is, on average, five persons, with dependents (children below 15 years and adults above 64 years of age) constituting about half of the household.

In about half of the surveyed households the primary production decision maker is female, though there are significant differences in the two major production regions defined by elevation. About half of the primary decision makers in low elevation areas are women, while 68 per cent of the primary decision makers in high elevation areas are male. This may reflect the subsistence orientation in the low elevation areas, relative to the more commercial orientation of banana production in the high elevation areas. Other household characteristics do not differ across the two production regions.

Household wealth is composed of livestock, landholding and other consumer durables (radios, bicycles, motorcycles and motor vehicles). Livestock include cattle, chickens, goats, sheep and pigs and are aggregated using both physical measures (livestock units) and market values (value of livestock). There is an average livestock value of Ugsh 234 845, with 30 per cent of the sample owning no livestock. Wealth measured in terms of other consumable durable goods was even smaller (an average of Ugsh 85 859), which is about US$ 46 of wealth.

On average, each household owns 1.5 hectares of land, with the landholdings much smaller, less than one hectare, in the highlands (Table 6), but the mean cropped areas in the two production areas do not differ significantly (Edmeades et al., forthcoming). Significant differences regarding banana production between lowland and highland farmers are also evident.

Table 6. Descriptive statistics of the surveyed sample

Variable name	Aggregate sample (N= 380)	Low altitude (N=285	High altitude (N=95)	P-value
Demographic characteristics				
Age	43.230	44.084	40.653	0.0589
	(15.35)	(15.574)	(14.419)	
Gender (1=male)	0.558	0.5157	0.684	0.0049
	(0.507)	(0.501)	(0.511)	
Education	4.832	4.885	4.674	0.6408
	(4.170)	(4.342)	(3.619)	
Household size	5.746	5.822	5.5157	0.3409
	(2.715)	(2.795)	(2.458)	
Value of Assets (Ugsh)				
1) Value of Livestock	246200	237948.1	270957.9	0.8002
	(526061)	(447107.4)	(71484.4)	
2) Farm land (hectares)	1.539	1.868	0.963	0.000
	(1.731)	(2.583)	(0.977)	
3) Durable consumer goods	85858.68	82175.44	96868.42	0.7692
	(338670.2)	(289265.8)	(457501.6)	
Non-labour income (Ugsh)				
1) Private assets	106087.1	7439.76	480512.8	0.256
	(1667922)	(43811.29)	(413332)	
2) Social networks	4330.46	4602.42	3594.05	0.811
	(1873.41)	(2194.06)	(3614.03)	
Farm characteristics				
Number of banana mats (total count)	283.43	208.495	464.905	0.000
	(334.677)	(230.863)	(456.49)	
Age of banana plantations (years)	16.490	9.946	34.672	0.000
	(20.246)	(10.238)	(27.59)	
Distance from tarmac roads (Km)	10.689	10.880	10.474	0.615
	(7.050)	(7.128)	(6.669)	

The scale of banana production is higher in high elevation areas than in low elevation areas (Table 6). Furthermore, households in high elevation areas have tended their banana plantations more than three times as long (a mean of 35 years, as compared to 10 years), allocate more than twice the cropped area share to banana production, and are more likely to grow the bananas in pure stands (Edmeades et al., forthcoming). Overall, access to infrastructure development is not significantly different in the two production areas.

There are potentially two household sources of non-labour income: (1) transfers to the household from private assets (i.e. rent from buildings, land) and (2) bilateral transfers. Credit from formal institutions plays a very minor role, as noted earlier. The descriptive statistics by Edmeades et al. (forthcoming) show that very few farmers in the sample area seek credit from formal sources (12.8%). Nevertheless, a significant number of households had access to bilateral transfers from their social networks (i.e. friends, relatives or acquaintances) that come in form of remittances, gifts or labour exchange, but the value of such transfers was small compared to the income received from private assets, such as rent from buildings, land or other assets.

Household participation in banana market transactions is described in Edmeades et al. (forthcoming). Some households choose not to participate, while others participate only as sellers, only as buyers, or as both sellers and buyers. The majority of households in the survey domain report some involvement in banana markets, although roughly a quarter of the households remain autarkic. In high elevation areas, about 90 per cent of market participation is associated with the selling of banana bunches at the farm gate. Buying banana bunches is a more common practice among households in low elevation areas (accounting for 32 per cent of market participation) than in high elevation areas. Such disparities in market participation between the two production areas reflect the geographical shift in the locus of banana production from the Central region to the south-western highlands, where bananas are transported and distributed across markets in the lowlands.

6.6. Summary

Knowing the source of data and collection procedures is important for the interpretation of any research results. This chapter has indicated that the research for this study used primary data collected from households from the villages selected to represent the domain. The sampling frame used and methods of data collection have been discussed. The data collection and survey instruments were designed taking into account the problems of recognition and the low literacy of farmers. Basic characteristics of the sample are also highlighted. The chapter indicates that the majority of households interviewed for this study had only a primary level of education, which is also the national average level of education for rural farmers, thus confirming that the sample is representative of banana producers in Uganda. Both female and male farmers were interviewed.

CHAPTER 7
MEASUREMENT AND ESTIMATION PROCEDURES

The solution to the optimisation problem in Chapter 5 defines a process of knowledge accumulation, indirect risk and the consequent choice of a management technology. This chapter provides a link between the production behaviour described in Chapter 5 with empirical estimation approaches. The chapter is divided into two parts. The first part discusses the estimation procedure, describing the econometric models used to analyse the use of management practices as well as household participation in associations and private social networks. The second part defines the empirical variables, describes their measurement and hypothesized effects, and puts them into the broader context of the existing literature.

7.1. Econometric estimation procedure

The selection of the empirical estimation approach was dictated by the nature of the data in the sample and the formulation of the economic variables in Chapter 5. The data contained about 20 management techniques farmers could use in the management of their banana plants. Some of these techniques were traditional in the communities and probably easy to apply while others were new and required special knowledge. Still others required additional inputs aside from labour. More importantly, the use of these techniques is a heterogeneous variable that can be measured in multiple ways, including frequency of use, a discrete (zero-one) variable, or a proportion. Constructing one variable or index that combines all of the techniques, or aspects of the techniques, used at the household level is not straightforward.

The econometric approach to estimating the use of banana production management practices consists of a number of steps. First, the 20 techniques were categorized into two major groups according to whether the technique was recommended primarily for soil fertility management or for mat management (also known as sanitation practice). The soil fertility management category contained eight techniques, while the other 12 techniques fell into the mat management category. The eight techniques in the soil fertility management category were aggregated into two soil fertility management technologies (i.e. mulching and manure application technologies) using factor analysis. The estimation results from the factor analysis also provided information that was useful in identifying other necessary statistical tests to be done on the data before final estimation and hypothesis testing.

The 12 techniques in the mat management category were further subdivided into three groups, namely planting technologies, post-planting but pre-harvest technologies and post-harvest technologies. Based on the results of the descriptive statistics, some techniques were discarded from the econometric estimation because of lack of variation, due either to near universal adoption or near universal non-adoption. Techniques excluded from analysis due to near universal adoption include: de-leafing and de-sheathing (both post-planting but pre-harvest management techniques), while those discarded due to near universal non-adoption were hot water treatment and pest and disease resistant banana varieties. Other techniques such as weevil trapping, corm cover and corm removal proved difficult to measure and hence were not included in the analysis. Ultimately, three mat management practices were included in the analysis: corm paring (planting technology), de-suckering (post-planting but pre-harvest technology) and post-harvest pseudo-stem management (post-harvest technology). Pseudo-stems have two components: the lower pseudo-stem and the upper pseudo-stem[1]. In the next subsection a summary of the data reduction method is presented. This is followed by a description of the empirical model and the procedure used in estimation.

7.1.1. Data aggregation, reduction and factor analysis

Data collected from surveys often come in the form of many correlated variables that are difficult to work with individually in statistical analysis. In the present study the survey data contained eight different types of organic materials used in the implementation of soil fertility management, i.e. (1) mulching with grass; (2)

[1] Bananas are normally harvested about one meter above the ground, the part that remains being what is here referred to as the lower pseudo-stem and the part that is cut off during harvesting being referred to as the upper pseudo-stem. After the fruit is cut off, the lower part of the pseudo-stem is also cut off and this is called stumping, while the upper part of the pseudo-stem can either be peeled or chopped up to destroy the breeding grounds of pests and also to facilitate rapid decomposition to recycle nutrients taken up by the plant during its growth. The whole process is what is here referred to as post-harvest pseudo-stem management.

mulching with crop residues; (3) mulching with kitchen residues; (4) addition of cattle manure; (5) goat manure; (6) pig manure; (7) poultry manure; and (8) composting of homestead-type refuse to make manure (hereafter referred to as compost manure).

Factor analysis, with a principal component option was first applied to the eight soil fertility management practices to identify the latent variables that characterize the association between the original variables and to determine whether they could be represented by a small number of components. Based on the criterion of an eigen value greater than unity, the eight soil management practices were grouped into four independent packages according to four unobserved factors (also called latent variables). The results of the factor analysis are summarized in Table 7.

Table 7. Rotated factor loadings of the soil fertility management practices on the four latent variables (indices)*

Variable	Index 1	Index 2	Index 3	Index 4
Crop residues	0.038	0.656	-0.007	0.472
Grass mulch	0.015	0.917	-0.034	-0.226
Kitchen residues	0.841	0.102	0.075	0.029
Goat manure	0.861	0.017	0.193	-0.043
Pig manure	-0.120	-0.013	0.740	0.121
Cattle manure	0.305	-0.054	0.695	-0.096
Poultry manure	0.777	-0.112	-0.307	0.066
Composted manure	0.010	-0.120	0.024	0.939
% Variance explained by factor	28.260	17.870	14.060	12.850

* Interpretation was based on a factor loading of $\geq$ 0.5

The four latent variables explain 73% of the total variance in the adoption components. The latent variables are ordered such that the first latent variable explains the high variation in the data, while latent variables that explain less than one variation are considered as less important and are not included. Next, the latent variables are interpreted depending on the association between them. In the context of the present analysis, four latent variables were generated from the eight soil fertility management practices and were respectively interpreted as (1) traditional technology, (2) mulching, (3) manure application and (4) composting techniques, based on the original variables.

Index 1, interpreted as the traditional technology, explains about 28% of the variance in the eight management practices. Organic household refuse (kitchen residues, goat manure and poultry manure) was highly correlated with this latent factor. All three management practices had positive effects, suggesting that the application of kitchen residues, goat manure and poultry manure are influenced by similar unobserved variables in the same way. These materials are collected in mixtures from the homestead as part of the cleaning activities and spread between mats to control weeds, though some farmers reported that this use was not deliberate. Farmers are advised to compost the household refuse and other organic materials before applying them to banana plantations to facilitate rapid decomposition and avoid the problem of scotching (Tushemereirwe et al., 2003). The technique of composting household refuse before applying it to banana plants was highly correlated (heavily loaded) with index 4. The technique of composting household refuse before applying it to banana plants instead of applying it directly seems to be used independently of other soil fertility management practices.

Index 2 consists of mulching techniques using the organic materials that are gathered from sources other than the banana crop (i.e. crop residues and grass). The use of this type of mulch material in banana production involves the costs of gathering, transportation and application, which reduce the returns from banana production, especially when the transaction costs to access markets are high. This factor explained 18 per cent of the total variance in the use of soil fertility management practices. Both types of mulching materials have coefficients with positive signs. Thus, factors that increase the use of grass mulching are also likely to increase the use of crop residues. Organic fertilizers from animals that are rarely kept in the homestead (cattle and pigs) were heavily correlated with factor index 3. These organic fertilizers also involve costs of access, transportation and application that may limit their use.

The second goal of factor analysis is to summarize the variables contained in the data set in a compact manner so as to be able to relate them statistically with other variables of interest. The application of factor analysis to the correlated variables clusters them into groups according to the latent variables underlying the observed correlation between the variables. The latent variable represents a linear combination of the original variables that captures most of the information in the original variables.

Let $v = \sum_{i=1}^{n} ac_i$ where a_i is a vector of the weights that are mathematically determined to maximize the variation of the linear composite with the original variables and c is a vector of the observable variables in the data set. The sum of the squared weights is constrained to equal one in order to maximize the variation in the composite variables $\sum_{i=1}^{n} {a_i}^2 = 1$.

Based on the results of factor analysis, different types of organic materials (c_i) that correlated highly (factor loading ≥ 0.5) with each latent variable were combined by simply adding the banana areas (measured during the mat count) under each organic material. These organic materials were typically applied in separate portions of the banana plantations and hence aggregation did not cause any serious measurement errors. The use of mulching technology is defined as the practice of applying crop residues (non-banana crop residues) or grass to mulch banana plantations. Similarly, the use of manure technology is defined as the practice of applying animal waste (from cattle and pigs) or composted manure to the banana plantations.

7.1.2. Econometric modeling and estimation of banana production management decisions

The decision to use and the extent of use of an improved banana production management technology represent two decisions, although they may be simultaneous in time. The household takes a decision on whether to use the improved management technology or not. Conditional on the decision to use the improved management technology, the household decides on the extent of use of the technology. The econometric approach used to estimate decisions regarding the use of banana management practices can be linked to the theoretical model through an index function model involving decisions about whether or not to use the technology and how much of it to use (Greene, 2000). Denote y^* as a vector of the unobserved demand for the improved management technology, as follows:

$$y^* = \alpha' Z + v \qquad v \mid Z \sim N(0,1) \tag{31}$$

Z represents a vector of explanatory variables cast on the right-hand side of equation (30); v is a vector of unobserved heterogeneity; and α is a vector of the parameters to be estimated. At the time of the survey demand had not been observed for some households and hence the structural equation cannot be estimated. Instead, a reduced form is estimated and the focus is on two management decisions, the discrete decision (to use or not to use) and the extent of use.

The household's decision to use the improved management technology is only observed when the latent variable exceeds a threshold value. Suppose the choice to use an improved management technology is observed when the latent variable is greater than zero and remains unobserved when the value of the latent variable is unknown. The reduced-form equation of the choice of the improved management technology can then be specified as:

$$\begin{aligned} y &= 1 \quad if \quad y^* > 0 \\ y &= 0 \quad otherwise \end{aligned} \tag{32}$$

We cannot observe the land allocation to the improved management technology for cases where $y = 0$, but only for a subset of the population for which $y = 1$. Data on the extent of use (δ^*) of the improved management technology is missing for those households who did not choose to use the improved management technology. Missing data for a set of explanatory variables leads to a censoring of the demand for the improved management practices for which $y = 0$ (Maddala, 1983; Greene, 2000; Wooldridge, 2002).

A Tobit regression model has been widely used in estimation when the dependent variable is observed within a limited range (Greene, 2000). Underlying the Tobit model is the assumption that the coefficients on the probability and extent of adoption are the same (Greene, 2000). Thus, the Tobit model fails to separate the two decisions that characterize the adoption of a divisible technology. The decision to use and the extent of use are also likely to be influenced by different factors (Wooldridge, 2002).

To test whether the Tobit model is a suitable representation of the processes affecting the use of improved banana management technology, Probit, Tobit and truncated regressions were estimated for each of the three technologies. The null hypothesis of equal coefficients was tested using the likelihood ratio statistic, where the restricted regression is the Tobit model and the unrestricted regression is the combined Probit and truncated regression. The results are summarized in Table 8. For most of the management practices the statistical significance of the test statistic leads to rejection of the null hypothesis that the coefficients are equal. The data therefore support separate estimation of the probability of use and extent of use decisions.

Table 8. A likelihood ratio test for the null hypothesis that the coefficients on the two management decisions are the same

	Value of the log likelihood function			Likelihood ratio test
Management practice	Tobit model	Probit model	Truncated regression	(P-value)
Mulching	-90.358	-147.680	134.690	0.000
Manure	-110.900	-163.500	91.900	0.000
Post-harvest pseudo-stem management	-197.620	-98.070	-83.820	0.219

The reduced-form model describing the banana area share allocated (the extent of use) to improved management technology in the population is specified as:

$$\delta^* \mid y=1 \quad = \beta' X + \varepsilon \qquad (33)$$

$$y = 1 \quad if \quad y^* > 0$$

$$y = 0 \quad otherwise$$

As defined above, δ^* is the optimal observed area share of the bananas under the technology, X is a vector of explanatory variables, and $E(\varepsilon \mid X) = 0$; it is assumed that the unobserved heterogeneity in the vector ε is uncorrelated with the exogenous variables.

The two management decisions can be estimated in two stages. The first stage uses a standard Probit, as specified in equation 31, and estimates the probability of using a management practice on the whole sample. In the second stage, an OLS regression can be used to estimate the extent of management on a sub-sample with non-zero technology use.

The fact that the demand for the improved management technology is now observed for a sub-sample of the population can create a sample selection problem that can result in inconsistent estimates in the extent of management equations (Maddala, 1983; Wooldridge, 2002). A Heckman two-step estimation procedure was used to test and correct for sample selection bias in the data. Although the share ranges from 0 to 1, the sample data indicate that all households have an extent of use of less than one. Thus, a model that accounts only for censoring at zero was applied.

The results of the first stage, described in the previous section, are identical to the Heckman first step. In other words, in the first step of the Heckman procedure, the choice of whether or not to use an improved management practice, is estimated for the full sample using a Probit model as specified in equation (31). Regression of the binary response variable (y) on the explanatory variables gives predicted estimates used in the computation of an inverse Mills ratio:

$$\lambda(\alpha^{'} Z) = \phi(\hat{\alpha}^{'} Z) \Big/ \Phi(\hat{\alpha}^{'} Z)$$

The inverse Mills ratio is a non-linear function of the density and distribution defined over the Probit estimates. The statistic captures the information related to the sample selection. The computed inverse Mills ratio is then included in the extent of management practices estimation in the second step. The statistical significance of the coefficient on the $\lambda(\hat{\alpha}^{'} Z)$ implies that the two error terms are correlated and hence confirms the presence of selection bias (Wooldridge, 2002). When the null hypothesis is not rejected, then the inverse Mills ratio should be included in the second stage estimation of the extent of use of management practices to correct for standard errors. When the null hypothesis is rejected, it means that a sub-sample of non-zero use of the improved management technology is representative of the population and the extent of use of the management practice can be estimated using OLS.

Hypothesis tests do not support the presence of sample selection bias in estimating the extent of use of mulching and post-harvest pseudo-stem management practices, but support it in the case of the use of manure. The test results imply that in the mulching and post-harvest pseudo-stem management equations, the sub-sample of households with non-zero use is representative of the population (Wooldridge, 2002). Consequently, the extent of use of these management practices was estimated by OLS regression on a sub-sample with non-zero use, while a Heckman model was used to estimate the extent of manure application.

According to the economic analysis developed in Chapter 5, the decisions regarding the use of banana management practices are also conditioned on farmers' perceptions of the biotic and abiotic problems, a random variable. Farmers' perceptions about these factors are influenced by the same variables that influence the use of improved management technology. Thus, we are dealing with a simultaneous equations model that is a function of exogenous variables, predetermined variables and an error term. Decisions about the use of banana management practices can be estimated as a function of direct measures of perception or by substituting for perception, using exogenous factors in the perception equation. The use of the direct measure of perception in the management use equations creates the problem of endogeneity. The observed indicator of perception is correlated with the error term ε of the demand equation, thus rendering the OLS estimates inconsistent (Greene, 2000; Woodridge, 2002). Consistent estimates can be obtained by using a two-stage least-squares estimator (2SLS) to correct for endogeneity (Wooldridge, 2002). If correctly specified, this estimation procedure will yield estimators with greater asymptotic efficiency than are attainable by the limited information method (Greene, 2000). However, this approach requires extensive data, which in most cases are not available. In addition, the full information method is complex when the null hypothesis of sample selection bias has not been rejected. Since the main focus of this study was to test the effect of social capital while controlling for other factors, the demand for improved banana management technology was estimated as a function of all exogenous variables cast on the right-hand side of equation 30, expressed as a reduced form.

The final statistical consideration is the possible simultaneity in adoption decisions for these management practices. The results of the factor analysis did not support the simultaneity of the manure and mulching adoption decisions. Even when the use of the two types of practices is determined independently, it is possible that the unobserved heterogeneity in the technology demand equations is correlated. In this case**,** statistical efficiency can be improved by joint estimation. Nonetheless, estimating the manure and mulching decisions jointly was not considered to be worthwhile since the set of explanatory variables is identical in all equations (Greene, 2000), implying no gains in statistical efficiency. Therefore each technology was treated separately.

7.1.3. Econometric estimation of household participation in associations and private social networks

In the theoretical analysis developed in Chapter 5, social capital was treated as a fixed variable. It was assumed that at the time of making the choice of a crop management technology, a certain amount of social capital stock that interacted with decision-making had been accumulated over the previous period. In this section, that assumption is maintained and the observed memberships in associations and the stock of private social networks resulting from household investment decisions is analysed. The purpose of this is to discern what characteristics of the households and/or the community explain the differences in these two forms of social capital.

Social capital accumulation is conceptualised borrowing ideas from the model of Glaeser et al. (2001). Participating in an association or joining a private social network is a decision-making process that involves comparing costs with benefits. Participation can be conceptualised as a cost-benefit decision that takes into account present expenditure in terms of time and other goods, as evaluated against immediate and future expected returns. It is reasonable to expect that when an individual contemplates joining a social network and investing in social interactions, he/she understands that there are benefits as well as costs involved. Benefits can take the form of informal credit, information, other material goods and/or emotional support. An example of a less tangible benefit is the direct happiness or social approval from others that an individual obtains from participating in a community association such as a burial society or religious organization. Costs may be in terms of utility loss from consumption foregone because time and valuable resources spent on socializing reduce the resources available for work. The individual views these prospects within a cost-benefit framework.

For different associations there may be different benefits and costs, which could motivate an individual to participate in various associations. Hence, analysing participation in associations involves the estimation of a binary decision whether or not to join a particular association and a decision as to the number of associations to join, a discrete-count variable. The number of associations a household participates in reflects the intensity of the household's social capital. Both decisions are based on the expected net benefit, which is unobservable to the researcher but assumed to be positive when the household decides to participate in the association. The econometric analysis of the two decisions is described below.

7.1.3.1 Decision to join an association

Denote Y_{ik}^{*} as the expected unobserved net benefit of participation in a local association. The decision as to whether to participate in any association k or not, is defined as a binary outcome (P) of an observed latent variable (Y_k^{*}). The latent variable underlying this decision is a linear function of its observed (W_k) and unobserved (ε_k) determinants, such that:

$$\begin{aligned} P_{ik} &= 1 \quad if\ Y_{ik}^{*} = \gamma^{A} W_k + \varepsilon_k \quad > 0 \\ P_{ik} &= 0 \quad otherwise \end{aligned} \tag{34}$$

Probit[2] estimation is appropriate for estimating models with such binary dependent variables. The model for the membership in each association was estimated separately.

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[2] Logit estimation is also generally appropriate for analyzing binary-response data, and under standard assumptions about the error term there is a priori reason to prefer probit estimation to logit estimation (Greene, 2000).

7.1.3.2 Intensity of group membership and private social networks

The number of memberships held by a household or the number of trusted people to whom a household is connected can be modelled as a series of discrete household decisions that sum across an aggregation of choices to a Poisson distribution. The Poisson model is a non-linear specification and estimates the effect of independent variables on a scalar dependent variable. The density function for the Poisson regression is:

$$f(S_i \mid W) = \frac{\exp(-\mu)\mu^{S_i}}{S_i} \qquad (35)$$

$$(S \mid W) \sim Poisson(\mu) \quad or\ NegBin \quad (\mu, q)$$

where the mean parameter (μ) is a function of explanatory variables that influence the household decision to participate in associations or private social networks, expressed as vector W and a parameter vector, γ^D. Included in the vector, W, are household and community-specific factors. The descriptive statistics and measurement of these variables are discussed in section 7.2.5. The scalar, S_i, is the dependent variable representing the household membership in associations or household density of private social networks. For a Poisson distribution, $E[S_i \mid W] = \mu = \exp(\gamma^D W)\ and \quad S = 0,1,2....s$, taking an exponential of ($\gamma^D W$) causes the expected count μ to be positive, which is required in a Poisson distribution (Long, 1997).

The validity of the Poisson model hinges on the assumption that the conditional mean is equal to the variance. In other words, a Poisson distribution is a single-parameter distribution with a mean equal to the variance $E(S \mid W) = Var(S \mid W) = \mu$. In most common applications, however, the conditional variance is greater than the conditional mean. A Negative Binomial regression that accounts for unobserved heterogeneity was fitted in order to test for over-dispersion. A Negative Binomial Regression model was also used to relax this assumption, allowing for over-dispersion in the data, such that $E(S \mid W) \neq Var(S \mid W) = \mu + \sigma = q$ (Greene, 2000). The statistical significance of the over-dispersion parameter against the null hypothesis of equi-distribution is rejected in the case of estimating the density of the private social network, implying that data on the number of trusted friends may not exhibit a Poisson distribution. A Negative Binomial regression was used to estimate the density of private social networks, while a Poisson model was used to estimate the density of membership in associations.

7.2. Definition and measurement of variables

In this section the empirical definition and measurement of the variables used in the empirical estimation are described. The section first discusses the methodological approaches to adoption studies. This is followed by the definition of the dependent variables used in the estimation of the use of management practices and social capital, elaborating on how each was measured. Then the independent variables are defined and their hypothesized effects and measurement are described.

7.2.1. Econometric approaches in technology adoption studies

Technology adoption studies can be categorized into three groups according to the type of data used: time series studies, cross-sectional studies and studies that use panel data (Besley and Case, 1993). Time series studies focus on the aggregate measures and the rate at which the technology was diffused in a specific community or region. Typical examples of such studies are Griliches (1957) and Mansfield (1961). This approach provides an insight into the community or regional characteristics and the technological attributes that influence the rate of technology adoption (Rogers, 1995), but is limited as to what it can say about the dynamic processes that influence technology adoption and diffusion.

Temporal studies that use panel data sets in which the same decision-making unit is observed over a period of time have been used to overcome such limitations. These studies capture both the dynamic processes that influence technology adoption and the impact of the technology on the adopting households and income distribution (examples are Foster and Rosenzweig, 1995), but they are rarely used because of the high cost of data collection. Instead, most studies on technology adoption make cross-sectional observations to classify the population into adopters and non-adopters, although such studies have been the subject of criticism in recent years (Besley and Case, 1993), thus drawing attention to methodological issues regarding cross-sectional studies of technology adoption.

Besley and Case (1993) classify the cross-sectional studies on technology adoption into two groups: (1) studies that take a snapshot to analyse the impact of farm and farmer characteristics on technology adoption; and (2) studies that use recall methods to go back over the history of technology adoption decisions. The second approach has advantages over the first in that it allows the dynamic process to be modelled in a manner that gives an insight into the importance of the impact of the previous state of nature on the current adoption decisions. However, as Besley and Case (1993) noted, this approach, while an improvement, still has limitations because adoption decisions may influence some explanatory variables, thus rendering them endogenous.

These limitations can be overcome by using recall to obtain information on the explanatory variables that are expected to influence adoption decisions before the first adoption decisions were made, but if the period of adoption goes far back in history, then the reliability of recall for such data is questionable. Another approach sometimes used to overcome endogeneity in the explanatory variables suspected to be influenced by previous adoption decisions is to estimate a system of simultaneous equations. Recent examples of such methodological approaches were applied in Negatu and Parikh (1999) while analysing the impact of perceptions on adoption decisions. Other researchers that have focused on new methodologies to deal with issues of the endogeneity and simultaneity of adoption decisions and incomplete technology diffusion include, amongst others, Smale and Heisey (1993) and Dimara and Skuras (2003). Smale and Heisey (1993) modelled adoption as three simultaneous choices: the choice of whether to adopt the component of the recommended package, the decision as to how to allocate different technologies across the land area, and the decision as to how much of certain inputs, such as fertilizer, to use.

Like most other studies, the present study uses cross-sectional data. As the descriptive information suggests, most of the management practices investigated had been in the communities long enough for characterizing adopters and non-adopters to yield reliable information regarding the adoption of these management practices (Appendix A).

Programme selection bias is also a common problem, related to inadequate definitions of the "counterfactual". This problem is typically addressed by the application of a treatment model, which implies a sampling strategy that includes a control and a treatment group. In the present study, the sample selection problem has been accounted for in the sampling frame for the study by allocating the sample to "exposed" and "non-exposed" areas.

7.2.2. Dependent variables for adoption models

Defining technology adoption at the individual level is a complex matter that depends on the nature of the technology, the local context and the research questions being answered (Dossy, 2003). Technology can be defined in terms of a discrete structure (0,1) when the technology in question is used exclusively, as in case of non-divisible technologies. When technologies can be adopted partially, a continuous variable is a more appropriate measure of adoption (Feder et al., 1985). Empirically, continuous decisions have been measured in terms of proportion, scale or intensity of use. Sometimes more than one continuous measure is used to reveal important information about the adoption behaviour (Smale and Heisey, 1993; Gebremedhin and Swinton, 2002). For example, Gebremedhin and Swinton (2002) found that the factors affecting the proportion and intensity of soil conservation were different.

Measuring the use of improved banana management technologies is even more complex due to the fact that the actual technology is made on the farm and there is no standard measure of adaptations. This perhaps means that modifications also vary across farms, which makes it difficult to establish a measure of the variants of the technology that can be generalized across the sample. Further complexity regarding the measurement of the intensity of use per mat is associated with the variability of mat sizes within the banana plot. Considering this complexity, the proportion (in terms of mat share) of use is a simpler measure for representing the extent of management with a specific technology. Hence the demand for an improved banana management practice is defined as the proportion of mats managed using a particular practice.

The term "use" rather than "adoption" is used in recognition of the complexity of defining adoption either in terms of a decision (discrete [0,1], proportional use [mat share], scale of use [number of mats], level of choices [per mat] and time of use [testing or farmer experimentation as compared to long-term use]). Hence the term "use" as used in the present study represents behaviour that could constitute either experimentation with the technology or final adoption after confirmation of the utility of the technology.

Although most banana management practices are continuous by nature, corm paring and de-suckering proved difficult to measure quantitatively. As such, for the purposes of this study, these practices are defined in discrete terms. Definitions of these and other management practices included in the analysis are presented below. A summary of the descriptive statistics on the respective adoption-dependent variables is presented in Table 9.

7.2.2.1 Corm paring

The use of "corm paring" technology is defined according to its discrete structure, i.e. 0,1 is measured as one if the farmer reported that the technology is used and zero if not.

7.2.2.2 De-suckering

De-suckering was measured as the average number of plants per mat. Farmers with an average of four or fewer plants per mat were considered to be adopters of de-suckering, while those with an average of above four plants per mat were categorized as non-adopters[3]. The variable is coded as binary. De-suckering could have been measured as an integer to allow more variability in the sample but this was made difficult by the variability of the mat plant population within a plot and averaging over the plot changed the variable from an integer to a continuous variable. Since the focus of the study is on examining deviations above the recommended number, irrespective of how much the farmer deviated from the recommendation, a binary indicator is appropriate.

7.2.2.3 Mulching, manure application and post-harvest pseudo-stem management technologies

The use of mulching, manure application and post-harvest pseudo-stem management were observed as continuous variables. Respectively, the use of mulching or manure application is defined as the proportion of mats managed with organic mulch or manure. Similarly, post-harvest pseudo-stem management is a continuous variable defined as the proportion of the managed pseudo-stems from which the fruit has been harvested and the technique involves either stumping, splitting or chopping. "Total pseudo-stems" is a count of all lower pseudo-stems and upper pseudo-stems left after harvesting for a period of one year. The use of these three management practices was measured for a period of 12 months (equivalent to one crop production cycle).

Table 9. Summary statistics of the adoption-dependent variables

Variable	Definition	Mean	SD
Corm paring	A binary indicator = 1 if the household reported use of corm paring before planting and = 0 if corm paring was not used	0.233	0.423
De-suckering	A binary variable = 1 if the average number of plants per mat is ≤ 4 and = 0 if otherwise	0.450	0.498
Use of mulch (δ_1)	Share of banana mats grown under mulching	0.199	0.260
Use of manure (δ_2)	Share of banana mats grown under manure	0.119	0.233
Post-harvest pseudo-stem management	Proportion of post-harvest pseudo-stems harvested that were managed either by stumping, splitting or chopping	0.320	0.286

[3] The recommended banana management technique is to allow three plants per mat but two or four may be left on a mat to adapt to the soil conditions.

7.2.3. Dependent variables for social capital models

Social capital is an unobservable asset, which is empirically measured through the use of proxies. In the present study, associations and private social networks were used as proxies for social capital. This subsection presents the definition of and measurement of the variables used to assess participation in associations and private social networks. The descriptive statistics for each variable are presented in Table 10.

7.2.3.1 Participation in associations

The decision to participate in associations is defined as binary (equal to one, if the household has membership in the association in question, and zero if not).

7.2.3.2 Intensity of participation in associations

The intensity of participation in associations at the household level is defined as the total number of memberships in associations held by household members. This is computed as the sum of the number of memberships held by household members.

7.2.3.3 Intensity of private social networks

The intensity of private social networks is defined as the number of trusted friends the household can rely on for help in case of any problem (i.e. the number of friends household members can talk to intimately, approach about any problem or with whom they can freely share a family secret). Conceptually, this measure is related to the proxies used by Godquin and Quisumbing (2005). The difference is that these authors disaggregated the measure by the hypothetical problem. Here, it was not considered important to disaggregate the measure by the hypothetical problem, since individuals may not have separate networks for separate problems or types of trauma.

Furthermore, the definition of private social networks used in the present study also differs from that of other definitions of social networks in that in this case relatives are excluded from private social networks. Relatives are considered to constitute a “given” social capital whose formation may be beyond the influence of the decision maker. It therefore constitutes an initial stock of social capital that could be included in the estimation as an explanatory variable rather than as an endogenous dependent variable.

Table 10. Descriptive statistics of the social capital dependent variables

Variable	Definition	Mean	SD
Membership in any association	A dummy variable = 1 if the household participates in at least one association and 0 if not	0.747	0.435
Membership in social association	A dummy variable = 1 if the household participates in either religious, culture-based or burial associations and 0 if not	0.610	0.488
Membership in informal saving and credit association	A dummy variable = 1 if the household participates in any informal credit and saving associations and 0 if not	0.222	0.416
Membership in agriculture-based association	A dummy variable = 1 if the household participates in any agriculture-based association and 0 if not	0.175	0.380
Household intensity of association	Total number of memberships in associations held by household members	2.232	2.256
Number of friends	Number of people the household members talk to intimately, with whom they share family secrets or who can be approached for help in case of any problem and to whom they are not related by blood	14.958	13.719

The household private social networks were elicited using a position-generator technique discussed in Lin (1999). The technique starts with representative positions in the society and the individual is asked whether he/she has ties to people in each position. By eliciting ties to people in each different position individually this method avoids the biases inherent in ego-centred network mapping methods. Ego-centred network mapping elicits a list of ties from the individual together with the relationships between the individual and the tie (Lin, 1999). Ties elicited using the ego-centred network mapping method are biased towards the stronger ties and the network may be under-reported (Lin, 1999). Both ego-centred network mapping and the position-generator technique emphasize the measurement of social capital as a resource embedded in social networks.

An alternative strategy for measuring social network capital focuses on the location within a social network as an indicator of the individual's social capital. Empirical measurement of network locations is accomplished by complete mapping of the network (Broeck, 2004). The advantage of this method is that it allows a detailed and complete analysis to be carried out of all network locations and embedded resources. However, the method assumes that a network has a defined boundary. This is useful when the focus of the study is on examining networking within a small location (such as a village) or organization, but not in the case of extensive surveys.

7.2.4. Independent variables used in adoption equations

Conceptual variables included in the analysis of the use of banana management are represented by the reduced-form equation and their operational definition was guided by the existing literature. Banana production is a semi-subsistence practice across much of the survey domain, with uneven access to markets and market participation, consistent with the non-separable case of the household model. When the consumption and production decisions are non-separable, the effects of comparative statistics are ambiguous. Thus, hypothesized effects are motivated by related adoption literature and previous information concerning banana production in Uganda.

The reduced-form equation for the improved management technology cast in equation 30 in Chapter 5 indicates that the banana area share allocated to an improved management practice is a function of the village wage rate for unskilled labor (w), the banana market price (P^B), household characteristics (Ω_{HH}), market characteristics (Ω_M), farm characteristics (Ω_F), exogenous income from private assets (I), formal information diffusion (Ω_D), farmer experience with the technology (τ), and different forms of social capital (Ω_{SS}). In this section, the empirical definitions and measurement of these variables are discussed. The descriptive statistics on each explanatory variable and the hypothesized effects thereof are summarized in tables presented in the text.

7.2.4.1 Household characteristics (Ω_{HH})

A number of household characteristics are hypothesized to directly or indirectly influence the choice and extent of use of the improved banana management technology. Some of these characteristics are specific to the farmer, who is defined in the present study as the primary production decision maker. They include age, gender and human capital. Human capital is represented by formal education, measured as the number of completed years of schooling. Education was identified in earlier adoption studies as an important household characteristic in adoption decision-making processes (Feder et al., 1985; Feder and Umali, 1993). Higher education is associated with the capacity to understand technical aspects related to the new technology but may also increase the opportunity cost of labour, which could reduce the use of labour-intensive management practices. Older decision makers are expected to discount the future heavily, implying that age is associated with low investment in techniques whose benefits and costs are far separated in time (Shiferaw and Holden, 1998). Gender is also included to assess whether there are any gender disparities in the use of banana management practices. Some practices such as de-suckering require greater physical strength for their implementation that may not be possessed by females, which could result in gender disparities in the use of management practices.

Other household characteristics included in the analysis were: wealth, household size and the dependency ratio. The effect of these factors on management decisions depends on the nature of rural market imperfections (Pender and Kerr, 1996). When labour markets are imperfect, households endowed with family labour may be more able to meet the high labour demand of improved banana management technology (i.e. mulching, pseudo-stem management and manure application) than their counterparts with smaller family labour endowments. Similarly, given the missing markets for organic fertilizers, households endowed with the assets (such as land and livestock capital) that produce these materials will be able to invest more in managing the soil fertility of their banana plantations.

Landholding (also referred to as farm size) was measured as the total number of per capita cultivable hectares possessed by the household. Data show that landholding size is positively correlated with the cultivated area. This implies that the supply of crop residues from other cultivation practices or grass needed to implement the mulching technology will be positively correlated with the landholding size. Since these fertilizers are produced on the farm as by-products of other farm activities, a larger landholding size should increase the capacity of the household to implement mulching technologies. Hence, landholding size may be expected to correlate positively with the demand for mulching technologies. Even when households have access to other land through hiring or borrowing, the high cost of transporting the residues to their family plots may impede their use in banana production.

Landholding can also act, through its influence on perceptions, to influence banana management decisions in the opposite direction. Boserup (1965) hypothesizes that increasing population pressure stimulates the use of land intensification techniques. This means that while more extensive landholdings per capita enable households to engage in crop production, which may result in organic materials for mulching, they are nevertheless associated with less pressure on the cultivable land. Low pressure on land, on the other hand, may suppress the perception of soil fertility problems, thus reducing the demand for soil fertility management practices.

The effects of owning livestock also appear to be ambiguous. The possession of livestock reduces the cost of access to animal manure, which may result in greater use being made thereof. On the other hand, the accumulation of livestock may imply a shift away from crop production and consequently a reduced pressure on the land, which could lower the perception of soil fertility problems and hence the use of practices related to soil fertility management. The number of livestock units is converted following Nkonya et al. (1998), as demonstrated in Table 11.

Table 11. Descriptive statistics of household characteristics (Ω_{HH})

Variable name	Description	Expected effect	Mean	SD
Income (I)	Net transfers from household private assets	+	106 087.00	1 667 922.00
Age	Age in years	-	43.08	15.67
Gender	Gender (1 = male, 0 = female)	+/-	0.55	0.51
Education	Completed years of schooling	+	4.56	3.86
Household size	Total household members	+	5.87	2.77
Landholding	Total hectares of cultivable land per household member	+/-	0.37	0.68
Livestock unit	Sum of cattle units (0.8), sheep (0.4), pigs (0.4) and goats (0.4), divided by age household head	+	0.03	0.04

Distortions in output markets encourage self-sufficiency in that output, implying that an increase in the consumer-worker ratio (dependency ratio), which increases the household consumption demand, will stimulate investment in production. However, when insurance and labour markets also fail, as is the case in rural Uganda, a higher consumer/worker ratio may increase the risk of starvation, which could limit investment in labour-intensive activities. Hence the effect of the dependency ratio on the use of improved banana management practices cannot be determined a priori.

The expenditure constraint in the estimation is represented by the total exogenous income received by the household as a net transfer in the form of interest from private assets (I) and income in the form of gifts and remittances from social capital (Ω_{SS}). Detailed information on the definition and measurement of bilateral transfers that accrue to the household from its social network are presented in section 7.2.4.5.

The exogenous income from household private assets (I) was defined as cash inflow in the form of rent from buildings or interest on previous investments. Households with access to this type of exogenous income are able to overcome liquidity constraints and can purchase farm implements that will enable them to save on labour or use the cash to hire labour. Hence they will be able to use and apply banana management practices more extensively.

7.2.4.2 Farm characteristics (Ω_F)

The household's decision to use an improved banana management practice and consequent demand for the technology is also hypothesized to depend on farm characteristics such as location, physical land factors and scale of production. Elevation, a sample stratification parameter, is expected to condition both the use of practices and perceptions. At high elevations the soil erosion potential is higher, which could affect farmers' perception of the soil fertility problem and consequent investment in mulching and/or manure, to conserve soil (Ervin and Ervin, 1982). Prior biophysical information also indicates that banana productivity potential is higher in high-altitude areas, which provides further incentives to use improved management practices. The high pest and disease pressure in low-elevation areas implies that the risk from these biotic factors is greater in these areas than in higher areas. The other factor positively correlated with the risk of biotic/abiotic factors is the age of the plantation. Older plantations may be associated with a higher risk of pest/diseases or soil fertility problems because of the length of time these constraints have had to accumulate. However, the age of the plantation could also be related to lower risk due to continued management efforts to mitigate the negative consequences of these constraints. Hence the effect of the age of the plantation is ambiguous.

Physical land characteristics are hypothesized to directly affect perceptions of biotic and/or abiotic factors (i.e. pests, diseases and soil deterioration) but to affect the use of management practices only through their impact on perceptions. These variables include: the slope of the farm, the moisture retention of the soil in the banana plot and the drainage conditions of the banana plot. The physical land characteristics were measured in qualitative form using a subjective measure reported by the farmer (Table 12). The slope of the farm represents the erosion potential, while the capacity of the soil to retain moisture indicates the capacity of the soil to support the high demand of the banana crop for water. Therefore, a low soil moisture retention capacity in banana plots should increase the demand for mulch and manure through its influence on perceptions. On the other hand, the counteracting effect of poor soil moisture retention capacity on the productivity of mulching or manure could lower the incentive to incur costly investments.

Table 12. Descriptive statistics of farm characteristics (Ω_F)

Variable	Description	Expected effect	Mean	SD
Elevation	Elevation at which the farm is located (1 = high 0 = low)	+/-	0.28	0.45
Physical land characteristics				
Slope of the farm	A dummy = 1 if the slope is rated steep and = 0 if otherwise	+	0.78	0.42
Soil moisture retention capacity	A dummy = 1 if the soil moisture retention capacity of the banana plot is rated low and = 0 if otherwise	+	0.21	0.41
Drainage conditions on the plot	A dummy = 1 if the drainage conditions on the banana plot are rated poor and = 0 if otherwise	-	0.39	0.49
Mats	Total number of banana mats grown	+	283.43	334.68
Age of banana plantation	Number of years the banana plantation has been in existence since its establishment	+/-	16.49	20.25

The drainage capacity of the banana plot is another land quality characteristic that may be important in banana production (Tushemereirwe et al., 2003). Bananas grown on poorly drained soils are more vulnerable to leaf spot diseases, which may stimulate perceptions of disease problems. Because of the increased perception of diseases, the decision maker may require more of those management practices that are capable of mitigating the effects of the diseases. However, since there is no effective control measure for these diseases, the likelihood of the diseases occurring may pose an exogenous risk to banana production and could discourage investment in costly banana management practices.

The scale of production (measured by the banana mat count) reduces the fixed cost of information acquisition per unit area, thereby increasing the benefits from adoption (Feder and O'Mara, 1981). Like the landholding size, the scale of production could also act through perceptions to reduce the demand for management practices. Both factors reduce the economic impact of biotic and abiotic factors on the household. However, the two factors work through different mechanisms to increase the demand for management practices, thus justifying the inclusion of both measures of farm characteristics in the estimation.

7.2.4.3 Market prices and related characteristics (Ω_M)

Market access was measured as a village-level variable. The level of infrastructure development, measured as the distance in kilometres from the centre of the village to the nearest paved road, was used as the proxy for physical access to the markets. The direct link between infrastructure development and the use of banana management practices is not clear. Improvements in road infrastructure reduce the costs of physical access to markets for bananas, but also enhance market opportunities for non-agricultural enterprises, thus increasing the opportunity costs of investing in agriculture and labour for banana production. In the latter case, the indirect effects on the use of land-intensive crop management technologies could be negative when road infrastructure improves.

Economic theory predicts that, all other things being equal, a higher market price for bananas will increase the net returns from the higher yields associated with better crop management technology, while higher input prices (e.g. wage rates) would reduce the returns and hence the incentive to use improved banana management technology. Because the banana farm-gate price was positively correlated with the wage rate, a ratio (P^B/w) of the average farm-gate price of bananas to the village wage rate was constructed for the estimation (Table 13). Note that prices were measured as village means to reflect high intra-village correlation relative to inter-village correlation.

Table 13. Descriptive statistics of market characteristics

Variable	Description	Expected effect	Mean	SD
Mean wage rate	Village unskilled mean wage rate (in Uganda Shillings)	-	1 630.00	696.85
Banana farm-gate price	Village mean farm-gate price for bananas (in Uganda Shillings)	+	125.99	50.61
Price/wage ratio (p^B / w)	Average banana farm-gate selling price divided by the average wage rate for hired labour	+	0.10	0.03
Distance	Distance from paved roads (in kilometres) to the centre of the village	+/-	10.69	7.05

7.2.4.4 Information diffusion parameters

The stock of knowledge was conceptualised in Chapter 5 as a shifter of the banana production function, which increases the net returns from banana production. The farmer's level of knowledge also affects the process of forming perceptions. The process of accumulating knowledge is unobservable but knowledge accumulates as a function of experience (τ), formal information diffusion parameters (Ω_D) and social capital (Ω_{SS}) for a given level of education. Information dissemination and diffusion parameters are hypothesized to affect the use of practices both directly and indirectly through perception formation. Formal diffusion parameters included in the estimation are extension and exposure to the new banana varieties. Extension is measured as the number of cumulative contacts with extension educators in the period before the commencement of the study. Exposure to the new banana varieties is a dummy variable =1 if the village was exposed and = 0 if it was not exposed (Table 14). Large, discrete differences in knowledge are hypothesized between villages that have been exposed to the new banana varieties and related information and those that have not. The positive role of extension educators in the adoption of agricultural technologies is well established in the literature (Feder et al, 1985; Feder and Umali, 1993).

Table 14. Descriptive statistics of the parameters of information diffusion

Variable	Description	Expected effect	Mean	SD
Experience regarding mulch (τ_1)	Years of mulching divided by age	+	0.25	0.24
Experience regarding manure (τ_2)	Years of manure use divided by age	+	0.11	0.17
Experience regarding mat management (τ_3)	Years of use of post-harvest pseudo-stem management, de-suckering bananas	+	0.45	0.51
Formal information diffusion (Ω_D)				
Extension	Number of cumulative contacts with extension educators	+	1.15	2.05
Exposure	Dummy = 1 if a village was exposed to the new improved banana varieties and = 0 if otherwise	+	0.50	0.50

Social capital and farmer experience represented informal means of generating or diffusing information. Experience with the technology affects both perceptions of biotic and abiotic factors and the use of management practices. The farmer's experience was measured as the number of years the technology had been used on the farm (corrected for age) (Table 14). The definition and measurement of social capital variables included in the estimation are discussed below.

7.2.4.5. Social capital variables (Ω_{SS})

The conceptual framework developed in Chapter 5 highlights two mechanisms, viz. exogenous income and social learning effects, through which social capital can influence household decisions about improved banana management technology. Because of the importance of social capital in the present study, a number of social capital indicators were included. These are: household density of membership in associations, norms of decision-making, leader heterogeneity in associations and bilateral transfers in the form of labour, cash and durable consumer goods. The descriptive statistics of these variables are summarized in Table 15.

Household membership density is defined as the number of household members who belong to at least one association. Household membership density reflects the household's capacity to acquire information from the social network and the extent to which household decisions are influenced by the decisions of other households. This variable is also expected to influence the use of banana production technology directly since it measures participation in associations engaged in economic activities, which may reduce expenditure constraints on labour use or the acquisition of organic fertilizers (Narayan, 1997). However, the number of household members who join an association can also influence the opportunity cost of time used for banana production. Hence the nature of the effect cannot be determined a priori.

Table15. Descriptive statistics of social capital variables (Ω_{SS})

Variable	Variable description	Expected effect	Mean	SD
Household membership	Number of household members who belong to at least one association	+/-	1.25	1.0
Leadership heterogeneity	A continuous index measuring the degree of leader heterogeneity in terms of livelihood or level of education higher than most group members	+	4.44	0.6
Norm of decision making	A continuous index measuring the degree to which decision making in associations is participatory	+/-	6.11	0.5
Bilateral transfers				
Net labour Transfers	Value (in Ugsh'000) of labour obtained from the social network less the value of labour supplied to the social network	+/-	339.26	8 153.5
Net cash transfers	Amount of cash (in Ugsh'000) obtained from the social network less the amount of cash supplied to the social network	+/-	-1 554.60	163 111.0
Net transfer of consumer durables	Value (in Ugsh'000) of other household items obtained from the social network less the value of those items supplied to the social network	+/-	295.76	39 791.6

Decision-making norms and the heterogeneity of leaders (in terms of livelihood and education) in associations were used as proxies for the characteristics of associations. Decision-making norms measure the group's ability to cooperate, share information while the leaders with higher education and livelihood status depict the opinion leadership in the association and its ability to network with other people beyond the village community. Both decision-making norms and leader heterogeneity are variables that are constructed at the village level.

The concept of "decision-making norms" is defined as the degree to which the members in an association participate in important issues of the association, computed as an additive index from responses to two questions regarding the selection of leaders and the decision making of their associations. Respondents were asked how important decisions were made. Responses ranged from 1 = only leaders participate, to 2 = few members participate, to 3 = all members participate. They were also asked how the leaders of each association to which they belonged were selected. The responses were: 1 = by outside agents; 2 = each leader chooses a successor; 3 = by small groups of members and 4 = by a vote of all members. The village index was computed by averaging the number of responses in the village.

The concept of "leader heterogeneity" is defined as the degree to which leaders of associations within a village differ from the rest of the people they lead, in terms of education and wealth status, computed as an additive index from responses to two questions concerning the wealth and educational status of each association leader. The responses were coded as follows: 1 = lower than most members; 2 = the same as most members; 3 = higher than most members. The village index was computed by averaging the number of responses in the village.

Participation in associations and group characteristics were measured following the work of Narayan (1997). Each respondent was presented with a list of different categories of associations compiled with the assistance of key informants and asked to indicate the associations in which household members participated. For each category of association in which the household had membership, the most active household member in that association was asked about the homogeneity of the association (in terms of religion, ethnicity, gender, education and income status), group size, number of meetings held over the last 12 months and member participation rate in those meetings, decision-making norms when selecting leaders or making other important decisions and leader heterogeneity (in terms of livelihood and education).

Narayan (1997) measured group characteristics using five attributes: (1) kin heterogeneity of membership; (2) income heterogeneity of membership; (3) group functioning; (4) group decision making; and (5) voluntary membership. The choice of these characteristics is based on the assumption that the contribution to social capital of being a member of each group is greater if the group is more heterogeneous across kinship groups, more inclusive, horizontal and better functioning. Next an index for village social capital was computed by combining the frequency of membership in associations with the characteristics of groups. Related measures have also been developed and applied in a different empirical context by, amongst others, Grootaert (1999) in Indonesia and Maluccio et al. (1999) in South Africa.

The advantage of a measure based on membership and group characteristics is that it incorporates both people's propensity to engage in collective action and the nature of the social interaction (whether bridging or bonding). However, by aggregating these two aspects of social capital into one index, it becomes difficult to know which aspect is more important when used in examining relationships. In the present study different aspects of associations are examined individually rather than combined in an index. It is important for policy makers to know which aspect is responsible for the observed relationship.

Bilateral transfers from social networks also constitute an exogenous income to the household. Bilateral transfers in the form of gifts, informal credit and labour are part of the major resources that rural households in developing countries exchange. These transfers can influence the demand for banana management practices directly when used in implementing the practices or indirectly by reducing risk aversion (Fafchamps and Lund, 2003). Bilateral transfers accruing to the household were measured for a period of 12 months by asking respondents whether the household had received any cash or any other items in the form of a gift, donation or free labour from people other than household members during the last 12 months. For items received by the household, the respondent gave the total amount received and for non-cash items the concept of willingness to pay was used to attach a value to the items so as to standardize those items across households. Similar questions were asked about the household expenditure on each item in the social network for the same period. The net transfer for each item was computed as the difference between receipts and expenditure within a social network (Table 15). The data allows for estimation of the effect of different forms of bilateral transfers on technology adoption. Since the majority of the transfers are not conditioned on the occurrence of a shock, the problem of selection bias is not expected to be important in the data. As such, the actual amount of transfers received is a representative measure of the household's access to bilateral transfers in the sample[4].

7.2.5. Independent variables used in social capital models

It is assumed that the decisions characterising participation in associations or private social networks specified in section 7.1. 3 are based on net benefits from participation. The net benefit that household (i) located in community (j) derives from participation

[4] Use of ex ante insurance networks in the analysis did not change the results.

in an association can be modelled as a function of individual-specific variables and community-level factors. The definition, measurement and hypothesized effect of each variable included in the estimation are described below.

7.2.5.1. Household-level factors

In the literature household-specific variables that may influence the net benefits from participation in an association or private social network include household wealth, education and demographic factors (such as age, gender, and household size). Household wealth (measured in terms of the possession of other household assets) may influence participation through budget constraints or the expected benefits (La Ferrara, 2002). The effect of wealth on participation in an association is likely to depend on the nature of the association. Because socially oriented associations are relatively cost-free, we expected them to be easily accessible by the poorer households and that wealth should not have much effect on participation. However, given the fact that the immediate need of most poor people is their survival, they are likely to see less benefit in socially oriented associations[5] while the richer households may derive benefits in the form of social standing in the village. We also expect wealth to positively influence participation in economically oriented associations because the benefits derived from these associations are high and because they require members to contribute resources that may not be affordable by the poorer households. Overall, wealthier households are expected to invest more in social capital than poorer households.

Education facilitates information acquisition about other people and hence increases the ability to cooperate as well as the confidence of the individual to speak up in a group. Less educated individuals may feel intimidated, especially when the group has better educated members with a high social status. In addition, education may enhance the productivity of social capital. Hence it is expected to be positively associated with participation in social capital accumulation. Age influences the way the individual

[5] It should be noted that specific associations are not mutually exclusive. Most social associations also provide informal economic services and functions, such as access to information that reduces the cost of transactions. Likewise, economic associations may provide opportunities for people of similar beliefs to interact. Therefore, the classification adopted here is based on the degree of orientation and is meant to simplify the exposition.

discounts the future and lowers the propensity to invest in social capital (Glaeser et al., 2001). Gender may create differences in participation because of differences in roles or constraints. Women, as compared to men, have a high opportunity cost of time, and gender norms in the community sometimes constrain their social interactions. Hence we expect male-headed households to invest more in social capital than female-headed households. Age, gender and education are personal characteristics of the household head. Other household demographic factors consist of the number of household members in different age categories. The descriptive statistics of these variables are summarized in Table 16.

Table 16. Household-level factors hypothesized to influence social capital

Variable	Variable description	Expected effect	Mean	SD
Age	Age of household head in years	-	49.87	15.41
Household members below 15	Number of household members below 15 years of age	+	2.53	2.41
Household members between 16- 50	Number of household members aged between 16 and 50 years	+/-	2.00	1.33
Household members above 50	Number of household members aged above 50 years of age	-	0.52	0.66
Gender	Gender of the household head = 1 if household head is male and = 0 if female	+/-	0.74	0.44
Education	Years of schooling of household head	+	5.58	4.35
Landholding in 2001	Total acres of land owned in 2001	+/-	3.79	3.28
Livestock in 2001	Total livestock units owned in 2001	+/-	1.15	2.14
Duration of residence in the village	Number of years the household has resided in the village	+	31.96	16.19
Distance to nearest post office	Distance in kilometres from the homestead to the nearest post office	+/-	1.42	2.39
Relatives	Number of relatives the household members can talk to freely and approach for help in case of a problem	+/-	4.67	5.78
Farm production orientation	A dummy = 1 if household head is primarily employed on the farm and = 0 if household head is primarily employed off the farm	+/-	0.66	0.47

Livestock units and the size of landholdings are the wealth indicators used in the analysis. Since decisions regarding the accumulation of assets and decisions to join associations may be made simultaneously, the previous household asset position in 2001 was used. A sub-sample of 100 households interviewed in the sample were also interviewed in 2001 under the project entitled “Reviving banana productivity in central Uganda” (see Chapter 6). Since 91 households were re-interviewed, the selection bias associated with attrition was not considered to be a problem. Using explanatory variables observed in 2001 in models of social capital measured in 2003-2004 helps reduce the endogeneity of the explanatory variables in the social capital formation. Of course, although observed in 2003-2004, some households could have joined these associations even before 2001 and the independent variables would still be endogenous. To check this, each respondent was asked to give the year he/she joined the association. For the sub-sample used in this analysis, the majority of the associational memberships (65 per cent) reported were acquired after 2001, thus supporting the assumption that the explanatory variables measured in 2001 are exogenous in the social capital equations.

The duration of residence in the community, measured as the number of years the household has lived continuously in the same village, proxies the household's connectedness to the community and hence its willingness to cooperate with others. The initial endowment of private social networks was measured as the number of relatives household members spoke to intimately and could rely on in times of need.

Distance from the homestead to the nearest post office is a proxy for the cost of communication. Households residing in less accessible locations may face high costs of communication that could constrain social interactions, since in rural areas face-to-face interaction is the main channel of social capital formation. This variable also captures the degree of physical access to markets and hence the interdependence among households. Hence the nature of association is not clear. Farm production orientation is a dummy variable measuring whether the household head is employed as a full-time farmer or works part-time off the farm. All household characteristics, except for wealth, were contained in the 2003-2004 data.

7.2.5.2. Village-level factors

Village-level factors included in the analysis are the social and economic heterogeneity of the village and the institutional environment, described in Table 17. The effect of social and economic heterogeneity is ambiguous. It can reduce group participation (Alesina and La Ferrara, 2000; Alesina and La Ferrara, 2002) or increase it if the population stratifies into homogeneous groups (Cornes and Sandlers, 1986). Social differences may imply differences in beliefs and social norms that could constrain free interaction in the village. Similarly, economic heterogeneity can create barriers to free interaction associated with differences in preferences that make it difficult for a group to reach an agreement.

Social heterogeneity was represented in the analysis by the continuous index measuring the degree of ethnic[6] fragmentation, computed with the formula used by La Ferrara (2002) as s:

$$F_j = 1 - \sum \Psi_{hj}{}^2;\ h = 1,\ldots h_j$$

where Ψ_{hj} is the share of respondents in village j who belong to the ethnic group h, and in each village there are h_j number of different ethnic groups. The index represents the probability that the two individuals drawn from the same village belong to different ethnic groups. Economic heterogeneity was represented by the village's educational heterogeneity, computed on the basis of the educational level of the household head as the standard deviation of the years of education of household heads in the village in 2001.

Table 17. Village-level factors hypothesized to influence social capital

Variable	Variable description	Expected effect	Mean	SD
Ethnic fragmentation	A continuous index representing the probability that two individuals drawn from a village in 2001 are from different ethnic groups	+/-	0.48	0.13
Education heterogeneity	This is computed as the standard deviation of the village's level of education	+/-	4.03	1.12
Number of NGOs	Number of NGOs operating in the village	+	1.61	0.79

[6] The concept of ethnicity is used here to refer to a social group of people with a shared tribal affiliation based on patrimonial lineage.

The number of NGOs active in the village represented the institutional environment. The institutional environment measures the incentives and level of information about group formation in the village and hence is expected to have a positive effect. Village asset heterogeneity variables used in the analysis were also contained in the 2001 data.

7.3. Summary

This chapter provides a link between the theoretical analyses presented in Chapter 5 and the econometric estimation procedure. A detailed overview of the economic relationships central to this study is presented and the estimation procedure for each economic relationship is indicated. Two important decisions regarding banana management are estimated in a two-step procedure, with the first step estimated as Probit and the second step as OLS, while correcting for selection bias where necessary. The first step aims at estimating the probability of using a given management practice and generates estimates that are used to compute the inverse Mills ratio included in the second step as one of the explanatory variables. The second step of the estimation focuses on the extent of use of management practices based on the relative demand for the practice. In the estimation of management decisions social capital is taken to be exogenous. The chapter also describes an empirical model used to estimate the determinants of social capital, hypothesized to be a function of household characteristics and village social and economic attributes. The decision to join an association is estimated as a Probit, while intensity of membership and private social networks are estimated as Poisson or Negative Binomial models.

Three methodological approaches to technology adoption studies have also been reviewed. Despite the inherent methodological limitations, cross-sectional studies still dominate research on technology adoption because they are simple and low-cost compared to panel data studies. The chapter ends with a detailed list and the respective measurement methods of the variables used in the analysis. Empirical methods and strategies were developed to measure technology adoption as well as social capital, borrowing ideas from the literature.

CHAPTER 8
DESCRIPTIVE STATISTICS ON BANANA MANAGEMENT AND SOCIAL CAPITAL

This chapter provides a summary of the descriptive information on social capital and banana management. Sample statistics on the rate and extent of banana management are compared across geographical locations and economic strata. The purpose is to summarize the data that are of economic relevance to this research in quantitative and qualitative terms.

8.1. Banana management

Farmers use a wide range of organic fertilizers and sanitation practices to manage their banana plantations. About 18 management practices were reported as being currently used by farmers. Among the management practices involving natural resources (also referred to as soil fertility management practices), mulching and manure application were widely used across farms. Nearly a third of farmers (about 30%) used soil and water conservation bands[1] (Table 18). Of those who used soil and water conservation bands, the majority did not follow the recommended procedures (i.e. the use of an A-frame while constructing the bands to ensure that they run along a counter line). In such a case, their soil and water conservation bands may not have been effective.

Spatial differences in the use of soil fertility management practices were observed. On average, mulching, animal manure and soil and water conservation (SWC) bands are more frequently used in high elevation areas (which are the south-western region) than in low elevation areas (Central and Eastern regions). This could be attributed to the high erosion potential coupled with high population pressure in high elevation areas as compared to low elevation areas.

[1] Other soil conservation structures (i.e. grass strips, hedgerows and drainage channels) were very rare and hence not considered for this analysis.

Table 18. Percentage of farmers using selected banana management practices, by elevation and exposure

Management practices	Elevation		Exposure		Aggregate sample
	Low	High	Exposed	Not Exposed	
Natural resource management					
Mulching	66.49**	91.92**	73.47*	59.38*	75.09
Animal manure	35.56**	64.64**	37.75	33.33	45.39
Composting	17.01	15.15	26.53**	7.29**	16.38
SWC contour bands	9.79	15.15	16.33**	3.12**	11.60
SWC other bands	12.37**	30.30**	19.39**	5.21**	18.43
Mat management (sanitation)					
Corm paring	18.88	14.29	32.96**	6.06**	17.34
De-suckering	73.46**	92.86**	79.38^	67.68^	79.93
De-trashing	95.41*	98.98*	97.94^	92.93^	95.62
Post-harvest pseudo-stem management	76.20**	97.89**	80.75	82.76	76.23
Corm removal	50.00	80.61	56.98**	34.34**	60.20
Weevil trapping	31.63	24.49	37.11	26.26	29.25

**, *, and ^ denote statistical significance at the 1%, 5%, 10% levels, respectively, in the difference of means or distributions across elevation and exposure.

Usage rates for the most common mat management practices (i.e. de-suckering, de-trashing and stumping, and post-harvest pseudo-stem management) were also significantly higher in high elevation areas than in low elevation areas. Farmers in higher elevation areas have a greater incentive to manage their banana plants well, partly due to the favourable production potential of the crop. Notably, low rates of use were observed for weevil trapping (29%) and corm paring (17%), i.e. the pest management practices, in both production areas (Table 18).

Statistical differences in the use of specific management practices are also evident according to exposure, although not for all practices. The rates of use for mulching, composting, and soil and water conservation (SWC) bands, corm paring, de-trashing, de-suckering and corm removal) were higher in exposed areas than in non-exposed areas. The rates of use of SWC contour bands and post-harvest pseudo-stem management in low elevation areas were observed to be slightly higher among relatively small landholders (<2 Ha), while there were no significant differences based on size for other practices (Table 19). Also, higher use rates for most of the management practices were found near to paved roads (Table 19), suggesting that improved access to markets and information may increase the diffusion of management practices.

Table 19. Percentage of farmers using selected management practices by landholding size and infrastructure development

Practice	Aggregate sample (N=294)	Landholding <2Ha (N=140)	Landholding ≥ 2 Ha (N=53)	Distance from paved roads <10km (N=137)	Distance from paved roads ≥ 10km (N=157)
Natural resource management					
Mulching	75.09	75.12	67.00	90.51**	61.54**
Animal manure	45.39	43.78	37.93	56.20**	35.9**
Composting	16.38	22.58	17.24	14.60	17.95
SWC contour bands	11.60	15.67*	8.04*	17.52**	6.41**
SWC other bands	18.43	15.67	10.34	32.12**	6.41**
Mat management					
Corm paring	17.34	20.71	13.21	11.68*	22.29*
De-suckering	79.93	74.29	73.58	92.70**	68.78**
De-trashing	95.62	97.14	94.33	99.27**	92.5**
Post-harvest pseudo-stem management	76.23	83.33^	72.93^	91.39**	58.43**
Corm removal	60.20	51.43	47.17	83.94**	39.49**
Weevil trapping	29.25	33.57	28.30	47.45**	13.38**

**, * and ^ denote statistical significance at the 1%, 5%, 10% levels, respectively, in the difference of means or distributions across elevation and exposure.

While many farmers report the use of soil fertility management practices, the average extent of use per grove (the average ratio of area in which the practices are applied to the total area of the grove) among the adopters is below 0.3 for soil fertility management practices. In absolute terms, households in high elevation areas grow more banana mats (about 60) under mulch but the share of the plantation under the two organic fertilizers (mulch and manure) was larger in low elevation areas than in higher elevation areas. These summary statistics imply a more binding constraint regarding access to organic fertilizers for farmers in high elevation areas who are also comparatively large-scale banana producers. There are no meaningful differences in soil fertility management practices by exposure, which suggests that elevation is a more important underlying parameter.

The extent of the use of mat management practices (stumping and pseudo-stem splitting or chopping) was significantly higher in high elevation areas compared to low elevation areas, but no statistical differences were observed according to exposure. In high elevation areas, an average proportion of about 0.56 of the total number of pseudo-stems were managed by stumping, splitting or chopping within a few days after harvest, compared to 0.27 in low elevation areas (Table 20).

Table 20. Share of banana mats managed with recommended practices among users

Management practices	Elevation		Exposure		All
	Low	High	Exposed	Not Exposed	
Natural resource management					
Share of plantation under mulch	0.35**	0.12**	0.38^	0.29^	0.26
Share of plantation under manure	0.30**	0.12**	0.33	0.24	0.22
Mat management					
Proportion of pseudo-stems managed by either stumping, splitting/chopping	0.27**	0.56**	0.32	0.36	0.32

**, * and ^ denote statistical significance at the 1%, 5%, 10% levels, respectively, in the difference of means or distributions across elevation and exposure.

Given the high percentage of farmers using the practices (Table 18 and 19) but low extent of use per farmer (Table 20), one would wonder whether knowledge about these techniques is indeed an explanatory variable in the use of banana management practices. In the case of some techniques, it is hardly possible to attribute the rate of use to awareness, but for others it is definitely important. The package of improved banana management practices includes new and hence less well-known techniques.

Table 21 presents information on farmers' knowledge and use of each management practice. There is a large discrepancy between awareness and the actual use of some techniques, such as soil and water conservation bunds, weevil trapping and the application of compost and animal manure. The main reason mentioned for not applying animal manure was that farmers lack access to it (i.e. do not have livestock), while others cited the problem of lack of farm implements, such as a wheelbarrow to carry the manure to the plot or assist in composting. Another reason given for not applying the techniques was that farmers had just heard about the technique and were still learning about it.

The least known practices are either relatively new[2] (such as chopping pseudo-stem, mulching away from the base of the plant and corm paring before planting) or comparatively complex (for example, contour bands). The method of mulching about one foot away from the base of the plant is a new component of mulching practice that is intended to deter pests from infesting the plant (Tushemereirwe et al., 2003). The method has not been significantly diffused into the community and only 20 per cent of the surveyed farmers were aware of it, while only 2.5 per cent of farmers had adopted the method. Similarly, less than half of the farmers knew about the recommended method of chopping the residues into tiny pieces to enhance pest control and rapid decay for the recycling of soil nutrients (Table 21).

Table 21. Percentage of farmers who know about and use the recommended banana management practices

Management technique	Knows	Uses
Soil fertility management		
Grass/crop residue mulch	92.49	75.09
Animal manure	87.03	45.39
Composting	69.97	16.38
SWC contour bands	46.42	11.60
SWC other bands	60.41	18.43
Mat management		
Corm paring	33.33	17.34
De-suckering	94.21	79.93
De-trashing	99.00	95.62
Stumping	85.71	75.85
Splitting/chopping pseudo-stems	88.44	75.85
Corm removal	76.53	60.20
Weevil trapping	62.22	29.25
Methods of implementation		
Complete peeling of the corm	37.20	22.90
Chopping the stem into tiny pieces	47.80	21.80
Chopping the stem into medium-sized pieces	51.80	16.00
Peeling off the sheath	78.80	43.40
Chopping corms after uprooting	73.10	27.70
Mulching/manure application about 1 ft a way from the mat	21.00	2.50

[2] With the increased incidence of biotic and abiotic factors, researchers have developed new methods of implementing mulching, manure application and residue management practices to help farmers cope with thee problems.

8.2. Household and village social capital

The significance of farmer-to-farmer exchange in disseminating information about banana technology is illustrated in Chapter 2 and underscores the role of village social capital in determining the use of banana technologies. Therefore, the purpose of this section is to present and discuss some of the descriptive statistics on the nature and extent of social interactions among agricultural households that may facilitate the diffusion of technologies in the selected banana producing areas. The emphasis is on the local associations and private social networks to which the households belong. The choice of descriptors is guided by the definition of social capital presented in Chapter 4.

To analyse the distribution of local associations in the rural communities of Uganda, data was stratified using three variables: altitude, region and distance from paved roads. Elevation was used as a stratifying variable in the sampling design because of the effect it may have on the agro-climatic conditions and hence on production behaviour. In this particular analysis, elevation represents differences in physical and climatic conditions that may be accompanied by differences in vulnerability and hence the need for interdependencies among households. Regions represent dominant cultural backgrounds (i.e. the Kinyankole, Kiganda and Kisoga cultures). Different cultures would have different norms and informal institutions that constrain human interaction. Distance from paved roads influences communication costs and therefore the cost of social interactions. Distance may also capture the effect of market integration, which could serve to reduce interdependence between rural households.

8.2.1. Local associations

Most of the villages in the banana producing areas foster active social organizations. Over 250 associations were identified, broadly categorized in Table 22 in terms of: (1) burial societies; (2) economic associations (formal and informal credit, agricultural and non-agricultural); (3) religious; and (4) culture-oriented associations. Burial societies and economic associations were more popular and widely attended across villages, implying that social interactions in rural Uganda are economically driven. Associations with purely social motives (cultural, religious, sports or choirs) were rare and where they existed membership was limited to a few households. Membership in local associations is summarized in Table 22.

Table 22. Percentage of households belonging to associations by elevation and infrastructure development

	Low elevation	High elevation	< 10km from paved road	≥ 10km from paved road	Aggregate sample
At least one association	70.63**	93.68**	68.40**	87.10**	76.38
Economic associations					
Informal credit	12.94**	48.42**	28.80**	12.90**	21.78
Formal credit	16.44**	4.21**	12.10	16.90	13.36
Non-agricultural	3.15	4.21	2.70	3.90	3.41
Agricultural	20.63	13.68	19.11	19.01	18.90
Burial societies	47.55**	92.63**	50.22**	69.70**	58.79
Religious	6.64**	23.16**	12.62	7.90	10.76
Cultural	2.80	4.21	2.33	3.92	3.15

Note: ** differences are significant at 1%.

Economically oriented associations appear to be popular both at village level and across the survey domain. A total of 180 economic associations were found in 20 villages, with an average of 8.25 associations per village. The number in a village ranges from a minimum of four associations to a maximum of 14. Associations oriented towards agriculture, credit associations and those engaged in non-farm activities were common among the households who participated in economic associations. Overlap of membership was also noted, implying that households derive different kinds of utility from different economic associations.

Burial societies are essentially a means of pooling resources to organize and pay for unexpected expenses such as funerals. There is in general only one burial society in a village, where rich and poor are both members of the same group. While there are no entry fees, every member is expected to contribute money and other resources towards funerals.

Religious and culture-based associations are formed to promote spiritual beliefs, though some were engaged in economic activities like training in development activities, provision of credit and saving for their members. Household participation in these associations was relatively low, with only 10% of the households reporting membership in religious associations and about 3% in culture-based associations (Table 22).

Statistical differences in the membership in economic associations and burial societies were evident according to elevation and infrastructure development. Membership in informal credit associations (also known as revolving saving and credit associations) was higher in high elevation areas and in villages with better access to paved roads (Table 22). Areas with more informal credit associations had fewer formal credit associations, suggesting substitution effects. No significant differences existed in the membership of other economic associations according to elevation and infrastructure development. In high elevation areas participation in informal credit associations was about 48 per cent, which is a relatively high rate of participation compared with 13 per cent in low elevation areas. Similar patterns were observed according to infrastructure development, while the reverse is true for membership in burial societies. There were also significant differences in household membership in burial societies though there is no meaningful relationship, but this is probably due to the fact that elevation is correlated with another variable important for participation in burial societies.

Analysis by region (cultural background) provides evidence that membership in burial societies is relatively low (rated at 22%) in the Central region compared to the Eastern (98%) and south-western (94%) regions, suggesting that the Kisoga and Kinyankole cultures encourage cooperation to provide social insurance, while the Kiganda culture appears indifferent (Table 23). This is also reflected in the mechanisms used to encourage cooperation. In the Eastern and south-western regions, over 80 per cent of the respondents reported that defaulters would face penalties, which could take the form of gossiping to expose the individual or social sanctions if the individual failed to cooperate, compared to only 40 per cent in the Central region. This poor capacity to cooperate could have negative implications for group-based approaches to rural development in the Central region.

In the Central and Eastern regions household participation in formal and informal credit associations was not statistically different, with membership in formal credit but not informal credit associations higher in these regions than in the south-western region. More households in the south-western region participated in religious associations than in other regions, though membership in these types of associations was generally low. There were no statistical differences between membership in agricultural, non-farming economic and cultural associations across regions (Table 23).

Table 23. Household membership in associations by region (%)

	Central (N=195)	Eastern (N=99)	South-Western (N=95)
At least one association	56.92[b]	100.00[a]	93.68[a]
Economic associations			
Informal credit	12.80[b]	12.10[b]	48.42[a]
Formal credit	16.90[a]	20.00[a]	4.21[b]
Non-agricultural	3.60	2.00	4.21
Agricultural	21.00	20.20	13.68
Burial societies	22.60[b]	98.00[a]	92.63[a]
Religious	7.70[b]	4.00[c]	23.16[a]
Cultural	3.60	10.00	4.21

"a" is significantly higher than "b" and b is significantly higher than "c".

Among all the households surveyed, 76 per cent belonged to at least one association (Table 24). The maximum number of association memberships for a household was eight. On average, households belonged to two associations, with the highest "intensity" (number of memberships per household) observed in high elevation areas (Table 24).

Table 24. Distribution of households by intensity of membership in associations (%)

Number of memberships	Low elevation	High elevation	10km from paved road (N=215)	≥ 10km from paved road (N=178)	Aggregate sample
0	29.72	6.32	31.78	12.92	23.88
1	36.71	27.37	26.64	45.51	34.38
2	15.73	35.79	19.63	21.35	20.73
3	12.94	16.84	13.08	15.17	13.91
4	2.80	8.42	3.74	3.37	4.20
5	0.35	4.21	3.74	0.00	1.31
6	0.70	0.00	0.47	1.12	0.52
7	0.70	1.05	0.47	0.56	0.79
8	0.35	0.00	0.47	0.00	0.26
Average number of memberships per household					
# Memberships	1.32**	2.12**	1.58	1.49	1.52

** Significant at 1%.

The results of a Kolmogorov-Smirnov test are consistent with the hypothesis that the underlying distributions of membership that generate the sample data are distinguishable by stratum (p-value= 0.00 with a two-tailed test). The difference of means is also statistically significant. No significant differences in the number of memberships per household appear to exist according to infrastructure development.

Rural households join associations with different orientations for various reasons. Most people joined associations with an economic orientation to improve their livelihoods. The majority of the respondents explained that economic associations improved their livelihood through access to credit, training and other income-generating activities (Table 25). However, only 46 per cent of the households surveyed were members of economic associations, compared to 60 per cent of households having membership in burial societies, which raises important questions about the determinants of participation. Burial societies offer social insurance against deaths for most people (82%) by meeting funeral expenses, but a few people join them to conform to community expectations. Religious and cultural associations help people to develop their beliefs but others join for economic reasons.

Table 25. Percentage of households giving the major reasons for joining informal associations*

Reason	Burial society	Revolving credit	Agriculture-based associations	Religious associations	Cultural associations
Improve livelihood	3.25	86.48	86.74	10.26	0.00
Social insurance	82.13	8.11	4.81	7.69	0.00
Benefits the community	1.63	1.80	1.20	2.56	30.00
Enjoyment/leisure	0.00	0.00	0.00	0.00	20.00
Spiritual beliefs	0.81	0.90	0.00	64.10	10.00
Conform with community norms	12.62	0.90	2.41	10.26	20.00
Friends/relatives joined	1.22	3.60	4.82	5.13	10.00
Employment	0.00	0.00	1.20	0.00	0.00
Meet other people	0.00	0.00	0.00	0.00	10.00

* More than one reason was given in some cases and hence column totals may exceed 100%.

8.2.2. Characteristics of associations

Types of associations differ in size and intensity at village level, probably due to differences in transaction costs. The economic (such as credit or income-generating) associations tend to be smaller in size (between 10 and 25 members) and there are relatively more of them at the village level, whereas in most cases there is only one burial society per village. The horizontal nature of economic associations and the high coordination costs involved in the larger associations where the incentive to renege is high motivates members to limit the size of such organizations. Meinzen-Dick et al. (2004) remarked that the number of groups in a community might reflect preferences regarding the structure of social interactions, though this is sometimes used as a measure of social capital (Narayan, 1997). Comparatively speaking, burial societies (which are found mainly in the Eastern and south-western regions) are large in size and more inclusive in relation to economic associations.

Overall, there were more economic associations per village in high elevation areas, although agriculture-based and formal credit associations were numerous in the low elevation areas (Table 26). The larger number of informal credit associations in high elevation areas could be associated with the land constraints in these areas. Lack of land to use as collateral in applying for loans from formal institutions could generate a demand for informal credit associations. Also, associations dealing in agriculture are more prevalent in the lowlands due to the relatively high level of recent interventions in agriculture by NGOs and NARO, especially in the Central region. Most of the agricultural associations were initiated by an external influence. Statistical differences in the number of informal credit associations were also found between strata defined by distance from paved roads, but it is interesting that this was not the case for the number of formal credit associations.

Table 26. Average number of associations in a village by elevation and infrastructure development

Density of associations	Low elevation	High elevation	10km from paved road (N=215)	≥10km from paved road (N=178)	Aggregate sample
Number of associations per village	11.27**	15.19**	2.94**	11.40**	13.06
Economic associations					
Informal credit	2.04**	5.99**	4.22**	1.79**	3.56
Formal credit	1.87**	0.43**	1.27**	1.77**	1.44
Agricultural	3.95**	2.23**	2.93**	4.06**	3.46
Non-agricultural	0.34**	0.80**	0.45	0.44	0.52
Culture-based	0.34**	0.60**	0.35	0.45	0.45
Religious	1.46*	3.79*	2.51**	1.66**	2.69
Burial societies	1.94**	1.39**	1.81	1.79	1.88

** Significant at 1%; * significant at 5%.

Most associations drew their membership from within the village's geographical boundaries, though religion and ethnic grouping are the most important sources of homogeneity for associations based on religion (Table 27). The social composition of other associations (burial societies and economic associations) reflected that of the village, both in terms of tribe and religion, suggesting that social heterogeneity may not be a serious barrier to social interaction in the villages selected for this analysis. Credit associations are more likely to cut across ethnic groups. Also, associations are not homogeneous with respect to gender.

The economic associations have relatively more wealth homogeneity than do burial societies and religious associations, but less than clan-based associations. Nonetheless, 47 per cent of the respondents reported that informal credit groups contained both poorer and wealthier households, and 29 per cent reported the same for formal credit groups (Table 27). The rich also join burial societies to conform to village expectations and for the sake of social approval. The mechanism to ensure cooperation is social sanctions against reneging. This increases the incentive to join burial societies for many village members and hence reduces the cost of participation per member.

In most cases, the leaders of the associations were of the same income status and educational level as most members (Table 27). Most respondents rated the trust in leadership highly, though this could have been biased by the fear that the enumerator, who came from the same village, might reveal negative information to the leaders. By far the greatest number of respondents reported that decision-making processes in associations were participatory as compared to dictatorial, implying that the participatory methods of development have been well absorbed by grass-roots people.

Table 27. Percentage of households belonging to village informal associations by socio-economic characteristics

Characteristic	Economic associations							
	All groups	Burial societies	Informal credit	Formal credit	Agricultural	Non-agricultural	Religious	Culture-based
Social heterogeneity								
Same village	71.35	77.80	77.48	55.56	62.92	72.73	48.57	70.00
Same clan	2.16	1.21	2.73	0.00	3.33	0.00	0.00	30.00
Same gender	21.64	15.32	34.55	24.44	34.44	18.18	28.57	30.00
Same religion	17.38	11.34	23.42	10.00	16.16	18.18	85.29	20.00
Same ethnic group	54.85	48.99	69.64	44.44	53.33	45.45	77.14	10.00
Income diversity								
Only middle-income	23.92	21.18	21.37	31.25	30.85	18.18	26.32	18.18
Excludes poorer	17.73	6.27	24.79	25.00	26.50	63.64	18.45	45.45
Excludes richer	8.43	7.84	6.84	14.58	8.51	0.00	7.89	18.18
Mixed income	49.91	64.71	47.01	29.17	34.04	18.18	47.34	18.18
Group decision-making process								
Participatory	82.24	92.08	87.50	57.45	69.88	83.33	67.57	70.00
Other	17.75	7.50	12.15	42.55	30.12	16.67	32.40	30.00

Overall, most associations required their members to either pay an entry fee or contribute resources or both. The specific mechanism of sanctioning adopted in most cases depended on the type of association. In burial societies where the membership is large and the costs of monitoring are high, defaulters would face a penalty. Penalties can take the form of spreading gossip to expose the individual or interest charged. Also, in most of the credit associations, failure to pay in time attracts an interest charge or the individual may be expelled from the group (Table 28). On the other hand, religious associations in most cases allowed free entry, and even where contributions were expected, no sanctions were imposed on individuals who failed to pay. For all associations, the rate of participation in the group meetings was rated high (Table 28).

8.2.3. Household private social networks

To analyse this structural form of social capital, a list of social networks elicited personally from farmers was first categorized according to the nature of the relationship with the household and then by occupation (or major source of livelihood). Using the nature of the relationship, the social network was categorized into "given" if the relationship was defined by blood (i.e. relatives) and "acquired" if the relationship was defined by friendship. Occupation was used as a proxy for the valued resources available in the household social network. It is assumed that the major source of household livelihood reflects the wealth status of the household (Lin, 1999).

Table 28. Households belonging to informal village associations by group functioning (%)

	Economic associations						
	Burial society	Informal credit	Formal credit	Agricultural	Non-agricultural	Religious	Culture-based
What are the requirements for joining the group?							
Pay a fee/contribute resources	76.23	90.65	85.71	63.09	83.33	50.00	60.00
Free entry	23.77	8.41	10.20	36.90	16.67	50.00	40.00
What happens if a member does not pay or contribute resources?							
Expelled	29.29	37.62	45.83	47.95	33.33	21.21	44.44
Faces penalty	56.90	42.57	41.67	15.07	8.33	15.15	11.11
Delay accepted	8.37	13.86	8.33	15.07	41.67	15.15	11.11
Nothing happens	5.44	5.94	4.17	21.92	16.67	48.48	33.33
Number of group meetings held last year	7.40	11.96	16.15	10.36	8.10	13.24	9.50
Rate the participation of members in group meetings							
Low	14.85	14.29	9.09	13.75	33.33	16.22	0.00
Average	10.07	10.20	11.36	8.75	16.67	27.03	40.00
High	75.10	75.50	79.55	77.50	50.00	56.76	60.00
What is the income status of group leaders?							
Higher than most members	17.50	17.31	41.67	23.81	8.33	13.16	10.00
Same as most members	80.42	82.69	56.25	75.00	91.67	86.84	90.00
Lower than most members	2.08	0.00	2.08	1.19	0.00	0.00	0.00
What is the educational level of the group leaders?							
Higher than most members	23.85	32.35	61.70	43.53	16.70	35.14	20.80
Same as most members	65.69	60.78	31.91	54.12	75.00	59.46	80.00
Lower than most members	6.29	4.90		1.18	0.00	2.70	0.00
Do not know	4.18	1.96	6.38	1.18	8.33	2.70	0.00
Rate the trust in the group leadership							
High	90.21	94.23	82.61	83.75	83.33	86.44	100.00
Neither low nor high	8.94	4.81	10.87	10.00	8.33	13.51	0.00
Low	0.81	0.96	6.52	6.25	8.33	0.00	0.00

In a decreasing order of importance, the social network in each category was classified as follows: (a) opinion leader, if the individual was involved in teaching, political or religious leadership[3]; (b) trader, if the individual was involved in agricultural or non-agricultural trade as their main activity; (c) livestock owner, if the individual was involved in crop farming or cattle keeping and (d) farming, if the individual was involved purely in farming, without cattle.

On average, each household was closely connected to 15 friends and 10 relatives, thus implying a larger "acquired" than "given" social network (Table 29). Households in high elevation areas appeared to be connected to more relatives than households in low elevation areas, though when analysed by region, the south-western and Eastern regions showed no significant differences. Interestingly, the network of relatives in the central region was smaller than in other regions (Table 30).

Table 29. Size of the entire social network by relationship and occupation by elevation

Type social network	Low elevation (N=291)	High elevation (N=98)	Aggregate sample
Total friends ("acquired" social networks)	14.92	15.11	14.93
Friends in farming	5.38*	7.28*	5.84
Friends in trade	4.30	3.65	4.13
Friends in teaching, political and religious Leadership	4.81**	3.07**	4.36
Total relatives ("given" social networks)	7.93**	13.97**	9.51
Relatives in farming	4.05**	8.89**	5.26
Relatives in trade	1.90^	2.67^	2.09
Relatives in teaching, political and religious leadership	1.84^	2.71^	2.06

Most of the household friends in high elevation areas appeared to be involved in farming, while the distribution was almost even in low elevation areas, implying a more horizontal "acquired" social network in high elevation areas than in low elevation areas. Analysis by region provides further evidence that the number of

[3] The lowest qualification for this category was political leadership or religious leadership at LC11. Teachers at primary schools and above were included.

friends in teaching, political and religious leadership is higher in the Eastern and Central regions, i.e. the low elevation areas, than in the south-western region, i.e. the high elevation areas (Table 30).

Table 30. Size of the entire social network by region

Type social network	Central region (N=195)	Eastern region (N=97)	South-western region (N=98)
Total friends ("acquired" social networks)	15.10	14.40	15.11
Friends in farming	5.52	5.50	7.28
Friends in trade	4.63	3.60	3.65
Friends in teaching, political and religious leadership	4.83[a]	4.70[a]	3.07[b]
Total relatives ("given" social networks)	4.85	14.03	13.97
Relatives in farming	2.34[b]	7.45[a]	8.89[a]
Relatives in trade	1.37[b]	2.94[a]	2.67[a]
Relatives in teaching, political and religious leadership	1.05[b]	3.41[a]	2.71[a]

"a" is significantly higher than "b" and b is significantly higher than "c".

Generally speaking, households try to bridge across different economic and social groups. However, the proportion seems to decline as one goes up in economic status, reflecting the limited number of such people present in the rural areas. Social homogeneity in this form of social capital was measured along the ethnic and religious dimensions. Overall, about 29.5 per cent of the friends that closely interacted with the household members were from different ethnic groups, while 34.1 per cent were from different religious affiliations from that of the household head. When village homogeneity is controlled for, the proportion of friends from a different religious affiliation remains low in a religiously heterogeneous village (≥ 50), estimated at only 36 per cent. The proportion of friends from different ethnic groups appears to increase (estimated at about 54 per cent) in highly ethnically heterogeneous villages (≥ 50). This result suggests that relationships embedded in the private social networks of rural households in Uganda tend to be more homogeneous along the dimension of religious affiliations. Bridging across religions still appears to be low, despite the government's efforts to discourage religious polarization. Therefore, households in villages that are more homogeneous in their religious affiliations are likely to have higher levels of community social capital.

Most of the interactions take place within the village where the household and its social networks reside. A household is able to meet most representatives of its social network within a period of one month. As elsewhere, network links in rural Uganda act as conduits for information and transfers. In the next section, bilateral transfers within the household social network are described.

8.2.4. Bilateral transfers

Exchange of gifts is a common practice in Ugandan rural areas. Gifts come in the form of food or assistance in kind, such as free labour, as well as durable consumer goods and cash. Zero-interest loans are another form of transfer that is common within social networks (Fafchamps and Lund, 2003), but these were less common in the Ugandan sample. The overwhelming majority (about 70 per cent) of transfers come as remittances from close relatives or from friends, in the form of gifts in cash or in kind, such as free labour, durable consumer goods or food (Table 31). Contributions towards expenditure after a shock (e.g. a burial or celebration) incurred by the household constitute 25 per cent of the transfers to the household (Table 31).

Table 31. Major purpose of transfers accruing to the household from its social network

Purpose	Share of the percentage inflow transfer
Celebrations	11.32
Burials	14.32
Gifts/remittances	73.83

The rate of participation in bilateral transfers was very high. About 95 per cent of the households interviewed reported having transferred part of their income to their social networks while 72 per cent of the households had received income from their social network (Table 32). Food in kind is the most common commodity used in bilateral transfers, followed by cash. Surprisingly, few households participate in labour exchange. This finding is contrary to prior expectations that imperfections in the labour market would motivate households to use informal means to transact in the labour market.

Table 32. Household participation in bilateral transfers (%)

Form	Inflow	Outflow
At least one form of transfer	71.62	95.75
Cash	28.12	79.84
Food	53.32	81.96
Labour	16.18	29.71
Durable consumer goods	18.83	37.14

On average, the resource out-flow to the social network exceeded the resource in-flow from the social networks. This could be due to the usual bias associated with a low willingness to report income compared to expenditure. Descriptive statistics are summarized in Table 33. No meaningful differences seem to exist regarding bilateral transfers according to elevation or region. In case of a problem, each household has nearly three people it can rely on for food, about two people it can turn to in financial difficulties, but only 1.6 people it can rely on for labour (Table 33).

Table 33. Average net transfers and the size of ex ante insurance social networks by elevation

Form of bilateral transfer	Aggregate sample (N=384)	High elevation areas (N=94)	Low elevation areas (N=259)
Net cash	-18 577.14	-55 442.55	-5 345.17
Net food	-9 861.46	-8 392.03	-10 302.90
Net labour	-3 263.15	-1 234.04	-3 426.44
Net other durable consumer goods	-3 740.37	-6 748.94	-3 691.89
Ex-ante insurance network			
Food	2.78	3.16	2.76
Financial problems	2.26	1.97	2.14
Labour	1.63	3.50	1.15

8.3. Summary

Few meaningful differences regarding the use of banana management practices according to elevation and exposure are evident. Use rates for recommended management practices appear to be much higher in high elevation, exposed areas and areas with better infrastructure development. Another interesting finding in this chapter is that social capital is not uniform throughout the study area. There is more household participation in associations in high elevation areas and, taken by region, the Central region demonstrates a low social participation. Results also show that most of the associations are oriented towards economic objectives, though a significant proportion of households are either constrained from participation or prefer not to participate in economic associations. Most of the associations are heterogeneous, with homogeneity along the economic dimension being common in economic associations. Private social networks are more homogeneous in terms of religious affiliation but not according to ethnicity. Finally, bilateral transfers are a common source of cash and labour income to the households but the amounts of net transfers are small.

CHAPTER 9
RESULTS OF THE STUDY

This chapter presents and discusses the results of the empirical estimation to test the effects of social capital and other hypothesized factors on the use of mat management (corm paring, de-suckering and post-harvest pseudo-stem management) as well as soil fertility management practices (manure application and mulching). Technology use decisions are considered in terms of a discrete decision (to use or not to use) and an extent-of-use decision (the share of the crop area allocated to these practices). The extent-of-use decision is defined for banana plantations in terms of the share of banana mats managed using the recommended practices. Findings on the factors that influence the social capital of farm households, another focus of this dissertation, are also discussed.

Variables included in the analysis of the use of banana production management practices were selected based on the theoretical analysis developed in Chapter 5, guided by the existing literature. Final specification of the explanatory variables in the estimating equations was constrained by multicollinearity considerations. The problem of multicollinearity in the explanatory variables can inflate the standard errors, causing failure to reject the null hypothesis when the data actually support its rejection, and thus lead to the wrong conclusions.

Each explanatory factor was partially correlated with other explanatory variables in the model to examine those factors that are highly correlated (results are presented in Appendix B). As indicated in the correlation matrix, the intensity of weevils measured at community level was highly correlated with the distance from paved roads and with the relative price of bananas. Hence, weevil intensity was omitted from the analysis. The problem of multicollinearity is often induced by the use of the Heckman procedure, when the explanatory variables in the first and second stage regressions are identical. Although non-linearity of the inverse Mills ratio allows the identification condition to be met (Wooldridge, 2002), multicollinearity can still be a problem. A variance inflation factor (VIF) technique in Stata 8.0 was also used to test for multicollinearity in the second-stage regression. All explanatory variables included in the estimation had a VIF of less than 5.0, which suggests that multicollinearity did not in fact affect the results.[1]

The chapter is organized into three major sections. The first section presents results regarding the determinants of the decision to use improved production management practices. This is followed by results regarding the extent of use of improved production management practices. Factors that influence household participation in local associations and private social networks, which proxy for social capital in this research, are presented last in section three.

9.1 The decision to use improved management practices

A Probit model was used to estimate the probability of a positive use decision. The summary of the results is presented in Table 34 while the full results are presented in Appendices C.1 to C.5. Marginal effects computed for the use decision in each model measure the expected change in the probability of observing a positive use of the selected technology with respect to a change in the particular explanatory variable at its mean value. In terms of the overall percentage of predictions correctly classified, the model performs well for all management practices, thus implying a good fit (Table 34).

Applying the same equation structure (set of explanatory variables) for all practices reveals that the determinants of the use of improved banana production management practices are technology-specific. There are few patterns that can be discerned across technologies. Thus, the interpretation of results is presented by practice and comparisons across technologies are made only when relevant.

Econometric findings confirm that all five groups of variables (household characteristics, farm characteristics, market factors, information diffusion parameters and social capital) shape the decision to use banana management practices.

[1] A variance inflation factor (VIF) greater than 10 indicates the existence of a collinearity problem (Kennedy, 1985).

Table 34. A summary of the Probit estimation of factors affecting the probability of using improved banana management practices

Variables	Mulching	Manure	De-suckering	Residue management	Corm paring
Household characteristics (Ω_{HH})					
Age	0.000	-0.006*	-0.004	0.001	-0.001
Gender	-0.052	-0.024	-0.157^	0.040	0.004
Education	0.009	0.008	0.013	0.011*	0.027**
Household size	0.017	0.018	0.019	0.010	0.013
Dependency ratio	-0.216^	-0.004	-0.031	-0.016	0.006
Livestock unit	0.018	0.109**	-0.048*	-0.019**	0.003
Per capita cultivable land	0.052^	0.023	-0.002	0.046*	0.013
Income from private assets I)	0.000	1.2E-06	6.7E-06	-6.4E-07	2.2E-07
Physical farm characteristics (Ω_F)					
Elevation	0.026	-0.036	0.851**	0.111*	0.215*
Poor drainage conditions	-0.023	0.148*	-0.026	-0.006	-0.082^
Moisture retention capacity	-0.138*	0.071	-0.076	0.028	0.054
Slope of the farm	0.037	-0.160^	0.137	-0.020	-0.111^
Age of the banana plants	-0.002	-0.003	-0.003	0.001	-0.002
Number of banana mats	0.0003*	0.0001	5.6E-06	9.8E-06	8.2E-05
Market factors (Ω_M)					
Distance from paved roads	-0.011*	-0.007	-0.016*	-0.009**	0.016**
Price/labour wage ratio	3.080**	2.847*	3.143*	1.299*	2.939**
Information diffusion parameters (Ω_D)					
Relative experience (τ)	0.814**	1.280**	0.172^	0.012	0.098*
Exposure	-0.017	0.099	0.326**	0.012	0.286**
Extension contact	0.015	0.020	-0.007	0.009	0.016
Social capital (Ω_{SS})					
Household membership density	0.021	0.047	-0.075	0.004	-0.036
Leadership heterogeneity	0.057	0.205**	0.240**	0.008	0.092*
Participatory decision-making norms	0.312**	0.261**	0.138	0.057	-0.256**
Net labour transfers	4.1E-06	2.4E-06	-2.4E-06	1.0E-06	8.9E-07
Net cash transfers	5.6E-07	6.6E-07	-2.4E-07	-5.3E-08	3.3E-07
Net transfers of durable consumer goods	3.4E-07	4.0E-06**	2.2E-07	-5.9E-07	5.6E-07
Observed probability	7.0E-01	0.426	0.432692	0.835	0.229
Predicted probability	7.9E-01	0.413	0.488	0.930	0.145
% Correctly specified	78.100	79.200	86.500	87.900	85.000
Number of observations	312.000	312.000	312.000	309.000	310.000
Likelihood ratio chi sq (25)	115.540	124.000	210.210	80.670	113.730
Probability > chi sq	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.3026	0.2913	0.4925	0.2914	0.341
Log likelihood	-133.159	-150.860	-108.322	-98.0792	-109.949

** Significant at 1%, * significant at 5% and ^ significant at 10%.

9.1.1. Effect of household characteristics

Most of the household characteristics included in the analysis (demographic factors, human capital and wealth) are typically significant in one or two equations. Household size is not significant in any equation. Other household demographic factors (i.e. age, dependency ratio and gender) appear to be important only in decisions regarding the use of technologies (i.e. mulching, manure and de-suckering) related to soil fertility management. Age and the dependency ratio are negatively associated with the probability of manure application and the use of mulching. Age is associated with a short time preference, which reduces the benefits of soil conservation technologies. Shiferaw and Holden (1998) also found that there was a negative relationship between age and the adoption of soil conservation structures in Ethiopia. The dependency ratio measures market failures in output markets. Imperfections in output markets encourage self-sufficiency in that output, and an increase in the consumer-worker ratio increase the household consumption demand and consequently production. However, when insurance and labour markets also fail, a higher consumer/worker ratio may increase the risk of starvation, which could limit the investment in labour-intensive activities.

Education (measured in terms of years of schooling) is a significant factor explaining the probability that a household will use corm paring and post-harvest pseudo-stem management. Education may induce a positive use of these practices through the increased ability to acquire information. Corm paring and some components of pseudo-stem management (i.e. chopping) are relatively new to farmers, hence the importance of education.

Endowments of wealth (livestock and landholdings), which are also productive assets in banana production, are more important in explaining variations in the use of banana management than household demographic factors. Livestock capital is important in the decision to apply manure, de-sucker and manage post-harvest pseudo-stems, but with contrasting signs. Livestock capital may influence the decision to use these practices through different mechanisms related to soil fertility. Ownership of livestock may reduce the cost of using manure but at the same time encourage farmers to grow more plants per mat since they may not be concerned about soil fertility. Similarly, the accumulation of livestock may imply a shift away from crop production and consequently a reduction of pressure on the land that could suppress the use of intensification techniques of recycling banana residues.

The per capita size of cultivatable landholdings (adjusted for areas under swamps and water bodies) has a positive sign but is only significant (at ten percent) in the decision to use mulch-related practices (grass or crop residue mulch and stumping and post-harvest pseudo-stem management). This finding supports the idea that the organic materials used in mulching are non-tradable as they are made on the farm using farmer resources. Landholding size increases the availability of mulching materials, thus enabling farmers endowed with this physical asset to overcome the problem of missing markets for organic mulch. The positive effect of landholdings on the decision to use post-harvest pseudo-stem management can be interpreted based on sociological considerations. Larger farmers typically have a higher social status in their communities, which could increase their expected social rewards, such as the recognition and approval that society accords a farmer for possession of a clean and healthy banana plantation[2].

The lack of statistical significance of per capita cultivable land in the use decision for other management practices (de-suckering, corm paring and manure application) could be related to the characteristics of these technologies, as stated in Chapter 1. Given that the materials for these technologies are made on the farm, there are no factors associated with land area that would affect the probability of use after controlling for the scale of production. Similarly, access to income from private assets does not seem to be important in the decision to use improved banana production management practices. These two findings reinforce the point that the materials for these technologies are not introduced so much as they are made on-farm. Consequently, farmers with a larger landholding or income from outside sources do not have any particular advantages in gaining access to the technology.

[2] Good sanitation in banana plantations is used as a symbol of wealth in some rural areas. One of the reasons farmers give when asked why they carry out sanitation practices, of which pseiod-stem management is primary, is that the plantation looks smart.

9.1.2. Effect of farm characteristics

Estimation results indicate that farm location factors (represented by elevation and physical land characteristics) are important determinants of the decision to use improved banana management practices, although the direction of the effect differs across technologies. As already suggested in the descriptive statistics presented in Chapter 8, disparities in the rate of use of the practices related to mat management between the low and high elevation production areas are evident. Households located in high elevation areas are more likely to leave the recommended three plants per mat, manage the pseudo-stems after harvesting the bananas and do corm paring at planting time than are those located in low elevation areas. However, elevation does not seem to be relevant in the use decisions for mulching with grass or crop residues and manure application.

The effect of physical land characteristics was captured in the qualitative indicators of the slope of the farm, soil moisture retention capacity and the drainage conditions on the banana plot. The slope of the farm represents the erosion potential and hence perceptions regarding soil fertility problems, which could stimulate the use of soil fertility improvements. At steeper slopes the use of management practices could also be higher because the disease threat is lower.

The results of the study indicate that the slope of the farm only explains the variations in the use of manure application and corm paring, with a negative effect on both practices (significant at ten percent). The negative effect of slope on the use of manure is surprising and contradicts the findings from other studies that slope is positively associated with perceptions about soil fertility problems that in turn encourage the use of soil fertility management practices (Mwakubo et al., 2004; Shiferaw and Holden, 1998; Ervin and Ervin, 1982). One possible explanation for this finding relates to the properties of the technology. While the erosion potential may induce the use of erosion control technologies such as conservation structures, it may at the same time act against the use of technologies whose benefits are likely to be lost when the erosion potential is high. Such is the case with the use of manure in banana production. At steeper slopes, the water run-off can easily wash the manure out of the plantation, thus reducing its benefits.

Similarly, a higher level of awareness about soil fertility at steeper slopes may discourage the use of management practices such as corm paring, which are not related to soil fertility management. This expectation is further supported by the negative effect of the measurement of poor drainage conditions on the plot, where perceptions about banana diseases are also expected to be high (Tushemereirwe et al., 2003). Poor drainage conditions may discourage the use of corm paring, a measure for controlling pests before planting, if farmers fear that the effort put into implementing the practice may be futile because of disease damage. This result suggests that the increase in biotic pressures in the banana production environment is likely to reduce the use of management practices not directly related to the management of the biotic factors.

Poor soil drainage conditions also affect the probability that a household will apply manure. However, the estimated effect is in the opposite direction to that estimated for corm paring (Table 34). The positive association between poor drainage conditions and the probability of using manure lends itself to the same explanation as that given for the findings regarding slope. The two results taken together suggest that soil moisture complements the use of manure. Poor drainage conditions in banana plots can also have an effect on us of manure through its effect on disease risk, since manure application and hence good plant nutrition increases plant vigour, which in turn enhances the tolerance for banana leaf spot diseases.

The capacity of the soil to retain moisture is a statistically significant factor only as regards the probability of using mulching practices. A possible explanation for the negative sign is that farmers may perceive soils with a low soil moisture retention capacity as naturally less fertile. The benefits of incurring the high costs of mulching may be slight when the farmers perceive the soil to be less fertile. Combined, the two results suggest a “Malthusian scenario,” where people may perceive a soil fertility problem but do nothing about it.

While landholding size increases the availability of mulching materials, thus enabling farmers endowed with this physical asset to overcome the problem of missing markets, the scale of production (represented by the banana mat count) may increase the incentive for mulching by reducing the fixed costs of information acquisition per unit area (Feder and O'Mara, 1981).

9.1.3. Effect of market factors and characteristics

Market factors are highly significant across all the equations. Village prices (for banana and labour) and the physical access to markets in general are important factors that explain variations in banana management among farmers. The banana price relative to the unskilled labour wage rate in the village was positively significant in all technologies included in the analysis, thus underscoring the crucial role played by market incentives in banana management decisions. After controlling for market prices, the probability of using an improved management practice seems to decrease with the distance from paved roads, except in the case of corm paring. The negative effect of the distance from paved roads on the probability of using soil fertility management practices may be related to low farmer perceptions of soil fertility on farms with poor access to markets for bananas. On plots near to paved roads, intensive banana production for commercialisation purposes may accelerate soil fertility depletion, which in turn stimulates farmer perceptions of the soil fertility problem, thus inducing a higher probability of using soil fertility management practices. Nkonya et al. (2004) found a similar result for the effects of market access on soil nutrient depletion in eastern Uganda. The positive effect of the distance from paved roads on the decision to use corm paring is not supported by the existing information. This could be a statistical anomaly.

9.1.4. Effect of information diffusion parameters

Information diffusion parameters included in the analysis were the exposure to new banana varieties and extension (formal diffusion mechanisms), as well as experience in years with the technology and social capital variables. Among the formal information diffusion mechanisms, exposure to new banana varieties seems to be the most important determinant in decisions regarding banana plantation management. Households in villages that were exposed to new banana varieties in the early 1990s are more likely to manage their banana plantations using the recommended de-suckering, corm paring and manure application practices.

The number of cumulative contacts with extension agents had the expected sign in most technologies but did not significantly shape management decisions. This is not surprising since most of the households in the survey had never had contact with extension agents regarding the management of banana groves. On average, each farmer reported an overall cumulative number of contacts with extension agents of only 2 times, a level too low to make any significant impact on decisions regarding the use of knowledge-intensive technologies.

Informal mechanisms of information diffusion were more important than extension. The farmer's relevant experience with the technology positively and significantly influences its use with a larger magnitude. The results also suggest that social capital, another informal mechanism that facilitates information diffusion, is important in the choice of banana management practices.

9.1.5. Effect of social capital

The effect of household-level social capital, represented by the intensity of household membership in associations and the characteristics of those associations (in terms of leadership heterogeneity and norms of decision making), was estimated. The importance of private social networks in overcoming different market constraints was captured through the inclusion of bilateral transfers in the estimation. The definitions and measurements of these social capital variables are presented in Chapter 7.

The results suggest that the number of household members that join associations has no effect on the probability that a household will use a given management practice. On the other hand, results support the hypothesis that the education and wealth status of leaders in village associations is positively associated with the probability of use. This variable was statistically significant in manure application, corm paring and de-suckering. As argued by Rogers (1995), leaders act as opinion leaders, and when they are more educated and wealthier they are likely to bring in more information from outside the village because they are connected to better social networks. Broeck (2004) found that farmers in Tanzania with secondary education and those with larger landholdings were more likely to seek information from outside their villages. Another possible explanation is that leaders who are educated and wealthier may generate positive externalities for technology adoption in the community because they are likely to adopt these practices and because people are likely to emulate their leaders.

Decision-making norms were also important in shaping household decisions regarding the management of banana plantations, but the direction of association differs across practices. Participatory norms that encourage consultations among members had a positive and significant association with mulching and manure application, but a negative association with corm paring. The positive association is consistent with the findings of Isham (2000) in rural Tanzania that consultative norms positively influence the adoption of fertilizers. There is no prior information to support the negative association. Nonetheless, it seems reasonable to expect that decision-making norms can have either positive or negative effects on the adoption of a practice. Negative effects may arise if psychological factors are important impediments to technology choice. This research did not investigate the psychological factors but the finding can also be explained based on information from other sources. Some farmers believe that when the corm of a young sucker is completely peeled (corm-pared), it will not germinate[3]. Such beliefs may have negative consequences for the adoption of the technology in communities with strong consultative norms.

Bilateral transfers show a weak association with the probability of using manure. Households that have better access to durable consumer goods from their social networks are more likely to use manure. This result can be interpreted to signify that households with better access to durable consumer goods[4] have more access to social insurance from their social networks, which reduces risk aversion and hence promotes the use of more resource-intensive technology. However, the magnitudes of the coefficients in both equations are too small. Net transfers were not significant in mat management practices.

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[3] The author heard some of these beliefs expressed during her interaction with farmers before this research.

[4] Durable consumer goods (such as cloth, kitchenware, books) were among the more expensive items exchanged within a social network. Exchange of livestock was very rare.

9.1.6. Likelihood ratio test of joint significance of groups of factors

The hypothesized relationships embodied in the decision-making model developed in Chapter 5 were tested jointly, using a likelihood ratio test for each management practice. The probability values showing the level of significance are summarized in Table 35. The first hypothesis seeks to test whether market imperfections are important in banana management decisions. The null hypothesis is that consumption and production decisions are separable. A lack of separability of consumption and production decisions may result from imperfections in the output market, factor markets or a combination thereof. As argued in Chapter 5, banana producers may face a combination of market imperfections (both output and factor markets).

The common approach used to test for market failures is that of testing the joint significance of household characteristics. The joint significance of household consumption characteristics (age, gender, education, household size, dependency ratio) was tested for each practice separately. Results show that joint significance tests of all household consumption characteristics hold for manure application (at ten percent), post-harvest pseudo-stem management (at five percent) and corm paring (at one percent). However, the rejection of the null hypothesis of separable consumption and production decisions in these practices does not clearly indicate which market imperfections are important. As already noted, these results may imply imperfections in the output market or the labour market. The results should therefore be interpreted with caution.

On the other hand, the joint significance test of consumption and production decisions supports the hypothesis of separability for mulching with grass or crop residues and de-suckering. This finding suggests that market failure in banana production is technology-specific. Edmeades (2003), in her study of banana variety choice, also concluded that market failure was cultivar-specific.

Table 35. Results of the likelihood ratio test of the joint significance of hypothesized factors in the decision to use specific management practices

Factors	P-value for the computed Likelihood Ratio for the joint significance of the specified factors				
	Manure	Mulching	Residue management	De-suckering	Corm paring
Household characteristics	0.084^	0.284	0.029*	0.119	0.001**
Farm production assets	0.000**	0.003**	0.000**	0.206	0.075^
Market factors	0.046*	0.004**	0.000**	0.033*	0.000**
Institutional information factors	0.000**	0.000**	0.028*	0.000**	0.000**
Exogenous income	0.000**	0.002**	0.065^	0.000**	0.006**

** Significant at 1%, * significant at 5% and ^ significant at 10%.

The joint significance test of physical farm capital (livestock units, landholding and land quality) reveals the importance of household endowments in banana production management decisions. The endowments of livestock capital and landholding highlight the importance of missing markets for mulching and manure materials in banana management decisions. As Pender and Kerr (1996) demonstrate, when perfect markets exist, factor endowments will have no effect on production decisions.

Statistical tests suggest that physical farm capital is more important in explaining variations in banana production management than household characteristics. Physical farm capital variables are jointly important in the use decision of all practices except de-suckering. These results suggest that endowments in production assets matter in use decisions, providing support for the notion that the non-tradability of some production inputs constrains banana management decisions. The statistical lack of significance of physical farm capital for the use of de-suckering may be associated with certain characteristics of this practice that could make farm endowments irrelevant to its use decisions. De-suckering is typically implemented by labour and farm-purchased implements (a panga or a hoe), which do not depend on physical farm capital.

Market factors and information diffusion mechanisms are highly significant and more important than household or physical farm factors in explaining variations in farmer decisions regarding the probability of use of management practices. The statistical significance of the combined market factors in all equations reflects the high importance of market incentives in banana production. This finding is an indication that banana production management decisions respond to market incentives.

Similarly, information diffusion factors that include formal institutions (exposure and extension) and informal information diffusion mechanisms were also jointly statistically significant in all the practices, supporting the assertion in Chapter 2 that banana management technology is knowledge-intensive. Although these technologies are typically not new to Ugandan communities, they have been subjected to frequent modifications by researchers to enable farmers to cope with the increases in biotic pressure, thus making the continued dissemination of information relevant to their adoption.

The joint significance tests of exogenous income combine variables related to bilateral transfers with net cash from rentals or interest. The statistical test results indicate that, although bilateral transfers appear less important when examined individually, they are jointly significant in all technologies. This is a key finding, given the scant information on the role of this form of social capital in technology adoption. An exception is the work of Hogset (2005) in a related study of soil conservation in Kenya.

9.2. Extent of use of management practices

The second aspect of the use decision for a divisible technology is the extent of use. The extent-of-use decision, or plantation share to which the practices are applied, is observed here only for mulching, manure application and post-harvest pseudo-stem management practices. Extent of use was estimated using two methods: ordinary least squares regression and the Heckman model. The Heckman regression model was estimated in the case of manure to account for the selection bias associated with missing observations for a given sub-sample due to the truncated nature of the dependent variable. The motivation underlying the use of either the ordinary least squares or the Heckman regression model is dependent on their statistical performance, i.e. whether or not the null hypothesis of sample selection bias was rejected. Results are summarized in Table 36 with reasonable measures of fit (R^2

=0.43 for mulching, 0.47 for manure application and 0.49 for post-harvest pseudo-stem management) for cross-sectional estimates. Full results can be found in Appendices C.6 to C.8.

Overall, estimation results show that most of the factors that were significant in the discrete decision to use management practices were also significant in the extent-of-use decisions. Some factors show contrasting effects in the two decisions. Results from the estimation of the extent of use are also technology-specific and are discussed accordingly.

9.2.1. Effect of household characteristics

Individual household characteristics show a weak effect on the extent-of-management decisions. As in discrete decisions, the effect of household characteristics on the extent of use is technology-specific. Among the household demographic characteristics, only household size is significant in two equations (manure application and residue management practices). Although household size was not statistically significant in the probability of use, it positively influences the extent of manure application and residue management practices, perhaps due to the relatively labour-intensive nature of these technologies. Household size can influence extent-of-use decisions through two mechanisms. In the presence of labour market imperfections, when the cost of hired labour falls within the price band, the household supply and demand for labour may be non-separable. This means that household size, which is a measure of the family labour endowment, could particularly affect the use of labour-intensive technologies. Household size can also affect production decisions for a staple crop through its influence on the consumption demand when the markets for the output are imperfect. So it is unclear which market imperfections the results imply.

Other household demographic variables (age, gender of the primary production decision maker and household size) were significant in only one equation. Older farmers are likely to allocate a smaller share of their banana plantations to manure application because of their high time preferences (Shiferaw and Holden, 1998). Age was also significant in the probability of using manure with a negative sign, reflecting the important role of time preference in the use of this practice.

Table 36. Estimation of the factors influencing the extent of use of selected banana management practices

Variables	OLS Model: Mulching		Second step Heckman model: Manure application		OLS Model: Post-harvest pseudo-stem	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Household characteristics (Ω_{HH})						
Age	0.000	0.001	-0.004^	0.002	-0.002	0.002
Gender	0.054^	0.031	-0.004	0.044	0.025	0.052
Education	0.009*	0.004	0.005	0.006	0.013*	0.007
Household size	0.007	0.007	0.021^	0.011	0.020^	0.011
Dependency ratio	0.134	0.084	0.039	0.112	-0.045	0.118
Livestock unit	-0.001	0.009	0.068*	0.029	-0.021	0.016
Per capita cultivable land	0.020*	0.009	0.009	0.012	0.039**	0.015
Income from private assets	0.000	0.000	0.000**	0.000	-1.6E-06	1.8E-06
Physical farm characteristics (Ω_F)						
Elevation	-0.111^	0.062	0.056	0.093	0.295**	0.090
A dummy for poor drainage conditions	-0.011	0.034	0.062	0.061	0.061	0.054
A dummy for poor moisture retention	-0.001	0.043	0.049	0.053	0.062	0.061
A dummy for slope	0.121**	0.038	-0.077	0.064	0.238**	0.063
Age of the banana grove	0.0001	0.001	0.0001	0.002	0.004*	0.002
Number of banana mats	-0.0001**	5.3E-05	-0.0002*	8.7E-05	0.000	0.000
Market factors (Ω_M)						
Distance from paved roads	0.003	0.003	0.002	0.004	-0.023**	0.004
Price/labour wage ratio	1.648**	0.571	1.487	0.950	3.310**	0.906
Information diffusion parameters (Ω_D)						
Relevant experience (τ)	0.037	0.103	0.409	0.349	0.206**	0.057
Exposure	0.037	0.039	0.147*	0.061	-0.040	0.063
Extension contact	-0.004	0.007	0.033**	0.012	-0.001	0.013
Social capital (Ω_{SS})						
Household membership density	4.5E-02*	1.8E-02	-0.027	0.028	-0.047	0.031
Leadership heterogeneity	9.6E-02**	3.2E-02	0.204**	0.068	-0.030	0.051
Participatory decision-making norms	-2.8E-02	5.9E-02	0.124	0.105	-0.037	0.077
Net labour transfers	1.4E-06	8.8E-07	5.1E-06**	1.8E-06	2.1E-06	2.2E-06
Net cash transfers	1.0E-08	2.7E-07	1.6E-07	3.7E-07	-4.0E-07	4.7E-07
Net transfers of consumer durables	-6.1E-07	5.6E-07	8.7E-07	1.4E-06	-1.2E-06	1.1E-06
Mills ratio	0.028	0.062	0.268^	0.143	6.7E-19	7.3E-19
_Constant	-0.542	0.381	-1.224	0.742	0.562	0.570
Number of observations (*n*)	213.000		128.000		257.000	
F (26, *n*)	5.380		3.39		9.030	
Probability > F	0.000		0.000		0.000	
R-squared	0.429		0.466		0.494	
Adjusted R-squared	0.349		0.329		0.440	

** Significant at 1%, * significant at 5% and ^ significant at 10%.

Male decision makers use mulching technology more extensively compared to their female counterparts. None of these demographic characteristics influence the extent of post-harvest pseudo-stem management. Similarly, the dependency ratio is not important in decisions regarding the extent of use of management practices included in the analysis.

As expected, education is positively related with the extent of use of management practices, but only statistically significant in the mulching and post-harvest pseudo-stem management equations. Other studies have also found a positive association between education and the adoption of soil conservation technologies (Mwakubo et al., 2004; Ervin and Ervin, 1982).

Household wealth (in terms of livestock units and landholding) is also an important determinant of the demand for improved management practices. Households with more livestock units allocate a larger share of their banana plantation to manure application. The greater availability of animal manure reduces the costs of manure application, thus stimulating demand. Exogenous income was not significant in most of the technologies, except in manure application. This could feasibly be explained by the fact that the implementation of manure application requires expensive implements, such as a wheelbarrow and a spade, which may impede a household with liquidity constraints from extensive use of the technology.

Estimation results also show that farmers with relatively large areas of cultivable land per capita mulch using grass or crop residues on a larger share of banana plants than those with less land (Table 36). As already discussed, the absence of a market for organic mulch materials explains the link between landholding and the demand for mulching practices. Farmers with large areas of cultivable land per capita also use post-harvest pseudo-stem management more extensively than those that are land-constrained. This result can be interpreted in the same way as in the case of discrete use decisions. The expected social rewards that society accords a farmer for good sanitation are likely to be higher among larger landholders because of their higher social status in the community. These two results suggest that an increase in population pressure will reduce the extent of mulching (with crop residues or with grass) and post-harvest pseudo-stem management but has no apparent effect on the use of manure. Thus, in the absence of appropriate technologies and policy incentives, a decrease in cultivable area per capita (a measure of population pressure on land) alone may not be sufficient to increase land-improving investments in these areas using mulch, contrary to Boserup's (1965) hypothesis.

9.2.2. Effect of farm characteristics

Location-specific variables (the elevation and physical characteristics of the farm) are also statistically significant in decisions regarding the extent of use of management practices. Elevation, a factor that generally defines the production environment, has conflicting effects among technologies related to mulching. Households in high elevation areas have a larger proportion of post-harvest pseudo-stems managed by stumping and chopping techniques but a smaller share of their banana plantation grown under grass and crop residue mulch. One feasible explanation could be related to the farming system, which could affect the access to the crop residues for mulching. The growing of annual crops is more common in low elevation areas, which could improve access to crop residues for mulching in these locations relative to the high elevation areas. This could, in turn, stimulate a greater demand for the recycling of banana residues in high elevation areas, also a mulch-related technology, to compensate for low access to other mulching materials. Hence the extensive use of the stumping and chopping of pseudo-stems practices, which are used to accumulate the residues for recycling. Elevation does not appear to be important as regards the extent of manure application.

Among the physical land factors, only the slope of the farm appears to be important with regard to the extent of management. The variable effect was positively related to the extent of mulching with crop residues and grass as well as post-harvest pseudo-stem management practices, both technologies related to mulching, which resulted in a greater magnitude (0.121 for mulching and 0.238 for pseudo-stem management) in both equations (Table 36). This result indicates that the soil erosion potential that threatens the loss of topsoil (which is also the most fertile soil) in high elevation areas will stimulate more extensive use of technologies related to mulching.

The age of the banana plot, another proxy for perceptions on biotic factors (i.e. pests, diseases and low soil fertility) has a positive effect on the extent of post-harvest pseudo-stem management practices. Long-established banana plantations may be associated with a greater accumulation of banana residues and consequently a higher awareness of pests and diseases, stimulating extensive use of pest and disease management practices such as post-harvest pseudo-stem management. The significance of this effect underscores the importance of the time component in the benefits derived from some management practices.

Although the scale of production had no effect on the probability of use of most management practices, it does influence the extent of soil fertility management using mulch. Households with larger banana plantations are more likely to mulch with crop residues or grass but less likely to apply soil fertility management practices (mulching and manure) to a larger proportion of their banana plantation. This finding probably reflects the lower economic impact of soil depletion on farms with bigger banana plantations. The finding is consistent with the prior information that agricultural growth in Uganda, as in many other sub-Saharan African countries, has tended to rely on expansion in area rather than on increased productivity (MAAIF and MFEP, 2000).

9.2.3. Effect of market factors and characteristics

Findings confirm that market-related characteristics are important determinants of the extent of use of improved management practices. Estimates of the variable “price/wage ratio” indicate that the greater the returns in regard to banana production relative to the opportunity cost of labour, the more use will be made of land productivity-enhancing practices, which require labour. The variable was positive in all three equations and significant in mulch-related practices (mulching with grass or crop residues and post-harvest pseudo-stem management). The results also suggest that the demand for post-harvest pseudo-stem management is likely to respond more to market incentives than to soil fertility management practices.

Most improved banana management practices are labour-intensive and higher costs of hired labour relative to the banana market prices will have a negative effect on the intensity of management. This means that rural development trends such as urbanization, which increase the opportunity cost of labour, are likely to have negative consequences for the management of the banana crop.

After controlling for market prices, the distance from paved roads is not significant at conventional levels in mulching with grass or crop residues and manure application, suggesting that a general increase in market access has no effect on the extent of use of these practices (Table 36). Instead, general physical access to markets appears to stimulate intensification techniques of recycling banana production residues. This is supported by the negative effect (significant at one percent) of the distance from paved roads, a proxy for physical access to markets, on the extent of post-harvest pseudo-stem management.

9.2.4. Effect of information diffusion parameters

Formal information diffusion does not appear to be important in the extent of use of improved management practices, except in the case of manure. Both extension contact and exposure were positively and statistically significant only as regards the extent of manure application. Experience with the technology, an informal mechanism of information diffusion, is also important only as regards the extent of post-harvest pseudo-stem management. The lack of statistical importance of experience in decisions regarding the extent of use of mulching and manure application implies that the observed partial use of these technologies can be explained by factors other than experimentation with the technology.

9.2.5. Effect of social capital variables

Results also indicate that social capital is an important determinant of the extent of soil management in banana production. The direction of association between social capital variables and management decisions has few patterns that are common across technologies. Household density of membership in associations was positively associated with the extent of mulching, but the effects were not statistically significant for manure and post-harvest pseudo-stem management. The finding that household membership density in associations influences the extent of mulching but does not influence the probability of use is interesting. It suggests that this aspect of social capital operates through various complementary mechanisms to influence the use of this technology. Mwakubo et al. (2004) also found that in the marginal areas of Kenya membership density increased the intensity of soil conservation technologies. One possible explanation is that households whose members have more participation in associations may have better access to the resources needed to implement mulching from their neighbours because, through associations, they learn to trust other people and also how to approach them (i.e. gain self-confidence). Since manure may require more expensive farm implements, such as a wheelbarrow, which are owned by very few households in rural areas, this kind of externality does not influence the adoption of manure application. Other practices are typically implemented with labour only, which is already controlled for in the analysis, and a panga, which is owned by almost every household. Also, households in villages where association leaders are wealthier or have higher education are likely to apply soil management practices to a larger share of mats in their banana plantations for the same reason as that given in the case of the discrete decision.

The role of bilateral transfers from social networks in decisions regarding the extent of mulching and manure use was also assessed. Net transfers of labour, cash and other durable consumer goods were included as measures of resources accessed from social networks. Most forms of bilateral transfers from social networks were not significant in the extent of their influence on use decisions, though net transfers in the form of labour were positively associated with manure application. Hogset (2005) also found a positive but weak relationship between bilateral transfers and the adoption of soil conservation technologies in Kenya. The weak effect of bilateral transfers on extent-of-use decisions may imply that although households use their social networks to reduce market constraints, the transfers are too small to stimulate extensive use of most management practices.

9.2.6. Joint significance test of a group of factors

The Chow test was used to determine the joint significance of a set of related factors for decisions regarding the extent of use of improved management practices. The same block of variables jointly tested in the case of the discrete decision was again used, as shown in Table 37. Results indicate that the extent of use of the three management practices is explained by different factors, with only two factors common across equations. Among the five groups of variables, market factors and institutional information factors are jointly statistically significant across all equations, thus underscoring the importance of information diffusion and market incentives in banana management. The importance of market factors as regards the extent of use of all management practices clearly indicates that banana management is driven by market incentives.

In addition to these two factors, variations in the demand for manure application, a soil fertility management practice, are also explained by exogenous income. On the other hand, the extent of use of technologies related to mulching (mulching with grass or crop residues and post-harvest pseudo-stem management) is explained by household characteristics and physical farm capital, in addition to market factors and institutional information factors.

The joint importance of household consumption characteristics in the mulching and post-harvest pseudo-stem management equation suggests that the demand for these practices is influenced by market imperfections. But, as already pointed out, the results do not identify which market imperfections are important. Results also show that the separability of production and consumption decisions holds for the extent of manure application, implying that the extent-of use decisions for this practice are not influenced by household consumption preferences.

The statistical significance of physical farm capital in the extent of use of mulching and post-harvest pseudo-stem management practices suggests that households with fewer endowments are constrained, using less of these management practices. This finding supports the assertion that the demand for banana management practices depends heavily on factor endowments. The importance of physical farm capital for the extent of use of these management practices may also be associated with perceptions regarding biotic factors. The quality of the land does have an influence on the perception of these biotic factors but can also affect demand directly by affecting the productivity of inputs. Hence the results should be interpreted with caution.

Finally, the hypothesis about the importance of exogenous income as regards the extent of banana management is of particular interest. The joint significance of all exogenous income variables (income in-flow from private assets and bilateral transfers from social networks) is tested. The hypothesis test suggests that exogenous income is only important in regard to the demand for manure but not in the case of mulching or post-harvest pseudo-stem management practices. This result suggests that liquidity constraints are binding only for manure application. This could be associated with the reliance on family endowments to implement most mulching practices, while manure application requires the purchasing of some implements for its implementation.

The importance of social support in the crop management decisions of banana farmers was then tested by excluding income from household private assets[5]. All variables representing bilateral transfers were jointly tested for their significance in regard to the extent-of-management decisions. Again, these variables are jointly important in respect of the extent of manure application but not in the case of other management practices. The lack of importance of bilateral transfers with regard to the use of other management practices could be attributed to the fact that they are too small to have any effect on the extent of use (see Chapter 8). This was also the finding of Hogset (2005) in a study of the effect of social networks on the adoption of soil conservation practices in Kenya.

Table 37. Results from the F-test of the joint significance of hypothesized factors in the extent of use of management practices

	P-values for the computed F-statistics for a joint significance		
Factors	Manure application	Mulching	Post-harvest pseudo-stem management
Household characteristics	0.241	0.003**	0.066^
Physical farming capital	0.314	0.003**	0.035*
Market factors	0.089^	0.000**	0.015*
Institutional information factors	0.003**	0.009**	0.012**
Exogenous income	0.007**	0.336	0.421

** Significant at 1%, * significant at 5% and ^ significant at 10%.

5 Results not reported but can be made available on request.

9.3 Determinants of household social capital

The results presented in the previous sections of this chapter highlight important associations between social capital and crop management decisions. The significant role of social capital in production decisions justifies any interest in its determinants. This section is devoted to just that. It should be noted that the selection of variables was based on literature that comes from other countries, and that variables that are unique to Uganda may therefore have been omitted.

The important challenge in estimating the determinants of social capital is its lack of a common definition. Participation in associations is a commonly used indicator of social capital (Alesina and LaFerrara, 2000; LaFerrara, 2002; Haddad and Maluccio, 2003; Godquin and Quisumbing, 2005) and was also used in this study. In keeping with the conceptualisation and definition of social capital in Chapter 4, household participation in another type of social capital called “private social networks” was also examined.

The regression explaining the probability that a household with specified characteristics will participate in a particular association was estimated with a standard Probit. Poisson and negative binomial regression models were used to estimate the probability for a count of memberships in associations or the number of trusted friends directly linked to a household. These models are suitable when the dependent variables take non-negative integer values, with some zeros for a given set of explanatory variables (Greene, 2000). The choice between a Poisson model and a negative binomial model was based on their statistical performance regarding whether the data inhibits the equi-distribution of variance and the conditional mean (Maddala, 1983; Greene, 2000). In the light of its statistical performance, a negative binomial model that allows for over-dispersion in the data was used to estimate the intensity of private social networks (Wooldridge, 2002; Greene, 2000). The results are summarized in Tables 38 and 39. To facilitate the easy presentation of results, this section is divided into two subsections. Factors that influence the decision to join associations are discussed in the first subsection and the estimation of the intensity of participation follows in the second subsection.

9.3.1. Membership in associations

Table 38 examines the probability of participating in at least one association in general as well as in specific associations[6] (social, informal revolving saving and credit associations and agriculturally oriented associations). The estimates presented are marginal effects, measuring the change in the probability of membership in the association for a given change in the explanatory variables, computed at the mean values. For convenience, table 38 presents summaries of the results while full results are presented in Appendices D.1 to D.4.

About 55 per cent of the sub-sample reported membership in at least one association, which is relatively low compared to the 74 per cent computed for the whole sample. However, given that the sub-sample used for the analysis comes from villages in close proximity to each other, the low variation in village-level variables restricts more thorough investigation as to why participation in this particular sub-sample is low. Nevertheless, the data provides some important insights into the variability of social capital at the household level. Comparing types of associations, participation in social associations (burial, religious and culture-based associations) was the highest, estimated at 32 per cent, while membership in credit associations (formal and informal) was the lowest, with 14 per cent of the households reporting membership in revolving saving and credit associations and 12 per cent of the households participating in formal credit associations. However, the combined membership in any form of economic association (formal or informal or other) was 38 per cent.

Membership in other economic associations was also recorded, but there was almost universal non-membership in these associations. As such, these associations were excluded from the analysis. They included non-agricultural production associations and formal credit associations. Formal credit associations were those that had affiliations with formal credit institutions. Members in these associations obtained their loans from formal credit institutions but required a group guarantee to access the

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[6] It should be noted that specific associations are not mutually exclusive. Most social associations also provide informal economic services and functions, such as access to information that reduces the costs of transactions. Likewise, economic associations may provide the opportunity for people of similar beliefs to interact. Therefore the classification adopted here is based on the degree of orientation and is meant to simplify the exposition.

loans. Although formal credit associations do exist in the study area, very few households in the sample seek formal credit. Indeed, only five per cent of the households included in this analysis and 13 per cent of the total sample sought formal credit.

Table 38. Probit estimation of the factors influencing membership in associations (standard errors in parentheses)

Variables	At least one association	Socially oriented association	Agriculturally oriented association	Revolving saving and credit association
Age of the household head	-0.006^	-0.014*	0.002	-0.005*
	(0.007)	(0.006)	(0.004)	(0.002)
Number of household members below 15 years of age	-0.005	0.028	0.021	-0.010
	(0.028)	(0.024)	(0.016)	(0.011)
Number of household members aged between 16 and 50 years of age	-0.088	-0.121*	-0.002	-0.022
	(0.058)	(0.058)	(0.034)	(0.019)
Number of household members aged above 50 years of age	-0.166	-0.014	-0.052	0.037
	(0.139)	(0.140)	(0.085)	(0.046)
Gender of the household head	-0.167	-0.315*	0.043	-0.062
	(0.147)	(0.171)	(0.079)	(0.081)
Education of the household head	0.035*	-0.001	0.020^	0.015**
	(0.018)	(0.015)	(0.011)	(0.008)
Landholding in 2001	0.049*	0.030*	0.025	0.002
	(0.024)	(0.018)	(0.016)	(0.006)
Livestock capital in 2001	0.063	0.073*	-0.027	0.019*
	(0.049)	(0.035)	(0.021)	(0.010)
Number of years in the village	0.002	0.004	-0.001	-0.001
	(0.004)	(0.0040	(0.003)	(0.002)
Distance from home to nearest post office	-0.049	-0.037	-0.001	0.002
	(0.059)	(0.041)	(0.021)	(0.007)
Number of relatives	0.009	0.001	0.035**	-0.001
	(0.017)	(0.011)	(0.012)	(0.004)
Farm production orientation	0.066	0.237*	0.165*	0.084^
	(0.146)	(0.099)	(0.065)	(0.044)
Number of NGOs operating in the village	-0.017	0.096	0.009	0.056*
	(0.083)	(0.068)	(0.059)	(0.031)
Education heterogeneity in the village in 2001	-0.071	-0.055	0.024	0.049*
	(0.067)	(0.059)	(0.045)	(0.031)
Ethnic fragmentation in the village 2001	0.620	1.042**	-0.486	-0.098
	(0.504)	(0.451)	(0.314)	(0.194)
Observed probability	0.539	0.311	0.189	0.144
Predicted probability	0.561	0.238	0.104	0.038
Likelihood ratio chi sq (15)	26.15	31.7	33.92	22.04
Probability chi sq	0.037	0.0071	0.0035	0.1067
Pseudo R2	0.213	0.284	0.3889	0.297
Log likelihood =	-48.34	-39.9505	-26.652743	-26.14

** Significant at 1%, * significant at 5% and ^ significant at 10%.

Both household characteristics and village attributes influence membership in associations. The age of the household head is negatively associated with membership in saving and revolving credit associations as well as participation in socially oriented associations. This result is consistent with the prior expectation and findings in the literature. Alesina and LaFerrara (2000), Haddad and Maluccio (2003) and Godquin and Quisumbing (2005) have all reported a negative relationship between age and membership in socially oriented associations. Households with more members between 16 and 50 years of age are also less likely to participate in socially oriented associations, perhaps due to the high opportunity cost of time for this age group.

The gender of the household head was in most cases negatively associated with membership in associations, suggesting that male-headed households were not likely to join associations, though this variable was only significant in socially oriented associations (i.e. religious, burial or culture-based associations). There is no prior information to support the significance of gender in these associations. One possible explanation is that religious associations, culture based-associations and burial societies may provide emotional support to female-headed households.

Overall, the education and wealth of the household (in terms of landholding) appear to be the most important factors associated with the decision regarding participation in associations. Households headed by better-educated individuals and those with larger landholdings are more likely to join an association. However, education appears to be important only in decisions regarding economic associations and not in the case of socially oriented associations. The positive role of education in the decision to participate in associations has been reported elsewhere (Haddad and Maluccio, 2003; Godquin and Quisumbing, 2005). Education may facilitate the acquisition and processing of information about the benefits of collective action as well others' willingness to help and their reliability, thereby enhancing trust in other people.

Both indicators of wealth (livestock capital and landholding) were positively associated with membership in social associations (significant at five percent) but only livestock capital was significant in the case of informal credit associations. The positive association with wealth in socially oriented associations disappears when burial societies are excluded from social associations, implying that the effect of wealth comes from the higher propensity to participate in burial societies. This suggests that associations such as burial societies that provide social insurance against unexpected deaths in rural areas are normal goods. Since burial societies require their members to contribute resources, the budget constraint may limit the poor households from participation. Godquin and Quisumbing (2005) also found in Philippine communities that individuals in the highest wealth quartile were more likely to participate in burial societies.

Production orientation is another variable that is associated with the decision to join associations. Households headed by full-time farmers are likely to join associations regardless of group orientation, compared to households headed by someone employed off-farm in a full-time capacity. There are alternative explanations for this result. First, the opportunity cost of time devoted to interactions in social associations is likely to be higher for household heads employed off-farm than for full-time farmers, which would constrain their membership in such associations. Another possible explanation is that off-farm employees are likely to deal with emergencies more easily than full-time farmers, since the former are likely to hold more liquid cash, thus reducing the incentive to participate. Agriculturally oriented households may have a higher demand for informal credit to finance their basic needs because they have a seasonal cash inflow. A less optimistic explanation is that agriculturally oriented producers are constrained from accessing formal credit since formal institutions prefer to lend to micro business enterprises while agriculture is considered risky[7].

The number of relatives living nearby and interacting with the household has a positive and significant effect on the decision to join an agricultural association, implying a positive interaction between private social networks and institutional forms of social networks. The number of relatives may reduce the aversion to risk and hence increase household willingness to participate in associations whose benefits are less clear to individuals. Households that interact closely with more relatives are also likely to be better informed about the benefits of the association and hence to join

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[7] This information was gathered from informal sources through interactions with community members during the data collection period.

agricultural associations, since entry is free of charge. As already indicated, most agricultural associations were initiated through the influence of external agents whose main motive was to use farmer groups to promote new farming methods.

Village economic and social heterogeneity also show some positive correlation with membership in associations but the variables were not significant in most of the estimations. The lack of statistical significance may be attributed to the low variation in these variables. Village heterogeneity in terms of education was positively and significantly associated with participation in saving and revolving credit associations, perhaps reflecting the notion that community heterogeneity may result in more participation by encouraging the population to stratify into homogeneous groups. As the descriptive information presented in Chapter 8 indicates, credit associations tend to be homogenous along the economic dimension. Similarly, ethnic fragmentation is positively and significantly associated with participation in social associations. As for educational heterogeneity, the positive association can be interpreted as indicating that higher ethnic fragmentation encourages the formation of socially homogenous groups and consequently increases the rate of participation in socially oriented associations.

9.3.2. Social capital intensity at the household level

The results of both the Poisson and negative binomial estimations of the factors that influence the intensity of household membership in associations and private social networks are summarized in Table 39. Full results the respective estimations are presented in appendices D.5 and D.6. Each model was statistically significant at less than one per cent.

Estimation results indicate that factors that were important in the decision to join associations were also important in determining the intensity of membership. Age reduces both the probability of joining social and economic associations as well as the intensity of membership, while education increases the probability and the intensity of membership. Education is also positively associated with the intensity of private social networks. According to the literature reviewed in Chapter 4, education has been consistently positive in its effect on the accumulation of social capital. As discussed earlier, education enables individuals to obtain and process information about the benefits of networking and the willingness of others to cooperate. It is also possible that education enhances the productivity of social capital. Godquin and Quisumbing (2005) found a positive relationship between education and network density in the Philippines. In contrast, Bolin et al. (2003) found that education did not have an effect on whether an individual had a friend or not. The contrast in results reflects the differences in the measurement of social capital and highlights the importance of a sound methodology in studies of social capital.

Table 39. Factors affecting the intensity of membership in associations and private social networks at the household level

	Associations (Poisson model)		Private social networks (Negative binomial)	
Variable	Coefficient.	Std. Err.	Coefficient.	Std. Err.
Age of household head	-0.029**	0.014	-0.002	0.008
Number of household members below 15 years of age	0.023	0.047	-0.058*	0.033
Number of household members aged between 16 and 50 years of age	-0.097	0.107	0.107	0.073
Number of household members aged above 50 years	0.090	0.293	0.302**	0.176
Gender of household head	-0.357	0.308	0.211	0.183
Education of household head	0.075**	0.031	0.103**	0.021
Landholding in 2001	0.063*	0.034	-0.019	0.025
Livestock capital in 2001	0.034	0.047	-0.048	0.035
Number of years in the village	0.001	0.009	-0.004	0.005
Distance from home to nearest post office	-0.182	0.158	-0.014	0.029
Number of relatives	0.027*	0.014	0.007	0.012
Farm production orientation	0.430	0.262	0.246	0.171
Number of NGOs operating in the village	0.191	0.151	-0.060	0.107
Educational heterogeneity in the village in 2001	-0.301*	0.138	-0.397**	0.085
Ethnic fragmentation in the village 2001	-0.551	0.803	-0.269	0.593
_Constant	1.960	1.006	3.784	0.624
Number of observations	90.00		89.000	
LR chi sq (15)	76.19		46.110	
Probability chi sq	0.00		0.000	
Pseudo R2	0.247		0.067	
Log likelihood = -116.300				
Likelihood-ratio test of alpha=0 Chi sq 2(01)			0.000	

** Significant at 1%, * significant at 5% and ^ significant at 10%.

Household wealth measured by landholding influences the intensity of household membership in associations. On the other hand, the results show no evidence of association between wealth indicators and the household intensity of private social networks. Social capital endowment, represented by the number of relatives, is positively associated with household intensity of social capital but only significant in the number of household memberships in associations. The number of relatives can influence the intensity of memberships through two mechanisms. First, relatives can persuade household members to join associations they belong to, hence acting through peer pressure. Another explanation is that since relatives may provide a form of social insurance, households that have many relatives are less likely to be risk-averse and therefore more willing to participate in different associations.

The results also suggest that households living in villages with high educational heterogeneity participate in fewer associations and private social networks. This result is consistent with the findings from a number of other related studies conducted elsewhere. To mention but few examples, Alesina and LaFerrara (2000) found that in United States localities, social participation was lower in more unequal and more ethnically fragmented localities. LaFerrara (2002), in a separate study of Tanzanian rural communities, found that inequality at the village level has a negative impact on the likelihood of membership in any group. As already discussed, heterogeneity at community level may reduce trust and cooperation, thereby constraining the formation and management of associations. No significant correlation between ethnic fragmentation and the intensity of participation in associations or private social networks is revealed by the econometric analysis.

CHAPTER 10
SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

This chapter presents a summary of the thesis. Relevant conclusions are deduced and the policy implications that emerge from the findings presented in the study are explored.

10.1. Summary of the study

10.1.1 Background

Agriculture is the most important economic activity in Uganda, providing income and employment to over 85 per cent of the Ugandan population, but its productivity has stagnated relative to population growth. Soil fertility decline and the increased incidence and intensity of pests and diseases are among the primary causes of low agricultural productivity in Uganda. Crop management technologies that could mitigate the negative effects of these biotic factors (i.e. pests, diseases and the deterioration of soil fertility) are available but the adoption thereof is lower than expected. A better understanding of the adoption process and constraints to adoption is needed to guide policymakers in designing appropriate policies to stimulate technology adoption.

Understanding the determinants of technology adoption has long preoccupied economists concerned with crop productivity potential in developing economies. Ample empirical work has been done on the determinants of technology adoption but most of the earlier adoption studies were focused on the green revolution technologies. In the post green revolution period, most crop management technologies recommended to small farmers in sub-Saharan African countries have been low external input technologies. The banana management technologies recommended for Ugandan farmers constitute a typical example of such low external input technologies. While these technologies have some advantages and are generally assumed to be affordable by resource-poor farmers, their characteristics may impede their adoption by many farmers. They tend to be location-specific and knowledge-intensive, and to substitute labour for capital. These technological characteristics mean that the factors that influence their adoption may not necessarily be similar to those that were important in the adoption of the green revolution technologies.

Despite the massive literature on technology adoption, some aspects of technology adoption have been under-researched. In particular, the role of social capital in technology adoption has received less attention in applied economics studies of technology adoption. There is an increasing interest in a paradigm that recognizes social capital as an additional asset in economic development. Among the reasons for this interest is the fact that social capital can facilitate information flow, reduce transaction costs and avoid collective-action dilemmas. This is critical for agricultural development in developing economies where the majority of the farmers have had fewer years of formal education and extension systems are weak. Furthermore, in developing economies transaction costs constitute a major challenge to agricultural development and mechanisms that can reduce these transaction costs will have a significant impact on positive development in these economies.

Although the literature showing that social capital and economic outcomes are related has been increasing, very few applied economics studies have tested the effect of social capital on the adoption of agricultural innovations. Moreover, those studies that have been undertaken to assess the importance of social capital in adoption decision-making processes have focused on information diffusion. The possibility that social capital may also generate resources in the form of cash or labour that could influence technology adoption has not been fully considered in the economic modelling of technology adoption. Furthermore, there is paucity of information on the determinants of social capital among agricultural households.

10.1.2. Purpose of the study

The purpose of this study was to examine the nature of the relationship between social capital and adoption of banana production management technology. The specific objectives of the study were to (a) conceptualise, define and measure social capital; (b) identify the determinants of social capital among agricultural households in Uganda; (c) examine the effect of social capital on banana production management decisions; and (d) determine other factors that are important in banana production management decisions.

To the researcher's knowledge, this is the first study to develop a model of technology adoption within an agricultural household framework that incorporates social capital and offers two explicit mechanisms through which social capital may be linked to technology adoption. By incorporating two mechanisms in the same analysis, the study was able to provide an insight into the mechanism that is likely to be important in linking social capital to the adoption of banana management practices

The main hypothesis of the study is: that the adoption of banana management practices is likely to be higher in households that (a) participate more in associations and have better access to labour and social insurance; (b) receive zero-interest credit/cash remittances from their social networks; (c) live in areas where association leaders have higher levels of education and livelihood; and (d) live in areas where social interactions are guided by participatory decision-making norms. The study also tested the hypothesis that household consumption and banana production management decisions are separable.

10.1.3. Research methods

Empirical analysis was based on the primary data collected in a survey of 400 banana-producing households in Uganda. These households were selected from the three major banana-producing regions (i.e. the Eastern, Central and south-western) of Uganda, using multi-stage random sampling methods. Survey instruments were designed to elicit detailed information on adoption, social capital and other household and village variables. The method of data collection, a combination of recall and observation, was designed somewhat differently from the conventional approaches in order to minimize the problem of measurement error. Colour photographs were also used to enhance farmers' recognition of the technology or constraint they were being asked about.

A combination of econometric methods was employed to analyse the data. A Probit model was used to estimate the probability of using an improved banana management practice and of participation in associations. The extent of use of improved banana management practices was estimated using two methods, namely ordinary least squares (OLS) and the Heckman procedure, to account for sample selection in some equations. Intensity of participation in associations was estimated using a Poisson model. A negative binomial model that allows for over-dispersion in the data was employed to identify the determinants of the intensity of participation in private social networks. Each technology and association equation was estimated separately because there were no efficiency gains in estimating a complex simultaneous system when the same explanatory variables were used across equations.

10.2 Major findings of the study

10.2.1 Use of banana management practices

The study found that there was a considerable diffusion of management practices among banana-growing households, but the share of the banana area treated using each practice was low. Considering the overall banana producing areas, less than 30 per cent of the banana areas are treated with soil fertility management practices (i.e. mulching and manure), but this percentage is much lower in high elevation areas. Constraints on access to organic fertilizers, which are more binding for farmers in high elevation areas, who are also comparatively large-scale banana producers, are likely to be an important reason underlying the smaller share of banana area allocated to soil fertility management practices. In high elevation areas, farmers try to compensate for the low use of external organic fertilizers by investing in the recycling of banana residues (through making extensive use of the stumping and splitting/chopping of pseudo-stems and the removal of extra suckers), but the same is not true in the case of farmers in low elevation areas. Neither soil fertility nor sanitation is extensively used in low elevation areas.

10.2.2 Determinants of use of banana management practices

The study results indicate that the choice of and demand for improved banana production management practices (i.e. mulching with crop residues or grass, manure application, de-suckering, post-harvest pseudo-stem management practices and corm paring) depend on a host of factors. All five groups of factors identified from the theoretical model were statistically significant in either the choice of or demand for improved banana management practices, or both, implying that the model appropriately describes the behaviour of banana producers in Uganda. However, the effects of most of the hypothesized factors were technology-specific, reflecting the heterogeneous nature of the practices and the fact that these factors may act through various mechanisms. This implies that the explanations of the results should be considered separately for the different technologies studied and their contextual settings. The null hypothesis of separable production and consumption decisions, a major analytical feature of the model of the agricultural household, was rejected for most of the practices, supporting the use of the non-separable household model to analyse the production decisions of banana farmers.

For simplicity of presentation, the determinants of banana production management decisions are organized under two themes. First, the results regarding the effect of social capital are discussed. This is followed by a discussion of the other determinants of the use of banana management practices identified from the study.

10.2.2.1 Effect of social capital

The study findings support the hypotheses that the use of banana management practices (a) increases with the number of household memberships in associations and household access to labour and social insurance from social networks; and (b) is higher in areas where association leaders have achieved higher levels of education and livelihood. The study results indicate that these aspects of social capital exert a significant influence on banana management decisions but, like many other variables, the effects were technology-specific.

Different dimensions of association-related social capital (number of memberships, leadership heterogeneity and participatory decision-making norms) are important in banana management decisions but the effects are specific to the particular practice as well as the form of social capital involved. A possible explanation for this is that these dimensions of social capital may work through different mechanisms that may be specific to the form of social capital involved, which influences the use of certain technologies but not others. Banana management practices also differ a great deal, which adds another source of heterogeneity. The most important conclusion from this finding is that the nature of the relationship between social capital and adoption of agricultural technologies depends upon the properties of the technology and the specific form of social capital used in the analysis.

After controlling for physical and human capital, households that have greater participation in associations are more likely to apply organic mulch on a larger proportion of their banana plantations than those with little or no participation in associations. However, this variable was not significant in the adoption of other practices, which suggests that it may influence mulching through mechanisms other than information diffusion. Mulching has been known in the communities for a relatively long period compared to some of the other practices studied. A possible mechanism through which membership density in associations may increase the extent of mulching is the access to resources, such as farm implements and land for cutting grass or growing annual crops, which could augment the use of mulching. Households that belong to many associations are likely to have access to such resources because, through associations, they learn both to trust other people and also how to approach them. Since manure may require more expensive farm implements such as wheelbarrows, which are owned by few households in rural areas, this kind of externality does not influence the adoption of manure application practices. Other practices are typically implemented using labour, which has been controlled for in the analysis, and a panga, which is owned by almost every household.

The study further indicates that the likelihood and extent of good banana management is higher in communities where associations are under the leadership of individuals having higher levels of education and a higher livelihood status. This aspect of social capital was significant in four out of five of the technologies included in the analysis. This is because individuals with a higher education and livelihood status are likely to be connected to external sources of information and people in powerful positions. When placed at the centre of social interactions in the community, by assuming leadership responsibilities in an association, people of higher social status generate positive externalities in the form of information or other resources (e.g. complementary inputs from external sources) for the adoption of new technologies because their higher social capital becomes accessible to more people in the community. This is because the majority of community members have attained low levels of education and are poor, implying that they have low social capital endowments of their own. Moreover, individuals with higher education and higher livelihood status are likely to be adopters and because people tend to emulate their leaders, there would be positive externalities for technology adoption. It can, therefore, be concluded that when people with a higher social status participate in guiding collective action within the community, the externalities for technology adoption generated from their participation are likely to be significant.

The effect of participatory decision-making norms on the adoption of banana management practices is ambiguous. Participatory norms of decision-making were positively associated with the use of mulching and manure technologies but negatively associated with use of corm paring. The negative effect in the adoption of corm paring was unexpected. The negative effect may be associated with the belief that when all the roots are removed, the sucker will not germinate. This finding re-enforces the assertion in the literature that social capital is double-edged. It can have positive or negative effects. It can, therefore, be concluded that while social capital facilitates the exchange of information, transformation and action, the information shared can result in either the adoption or non-adoption of the technology, depending on the contextual setting.

The analysis also reveals that labour transfers and social insurance from private social networks positively influence decisions regarding the use and extent of use of manure, a labour-intensive soil fertility management practice. This is evidence that agricultural households also use their social capital to compensate for high transaction costs in the labour and financial markets. However, the magnitude of the coefficients of these bilateral transfers was too small to be considered important. This finding implies that though bilateral transfers may be used to compensate for the high cost of transactions in the market, these do not entirely overcome market constraints when it comes to banana production management decisions. Institutional social networks (i.e. associations) are likely to be more important than private social networks. However, this should not be taken to mean that private social networks are not important in the adoption of agricultural technologies. The insignificance of bilateral transfers with regard to most technologies and the small coefficients regarding the use of manure may be related to the nature of the technologies studied. Their effect in other studies should also be investigated.

10.2.2.2 Other determinants of the use of banana production management practices

Other important determinants of the adoption of banana management practices identified in the study include market infrastructure, educational programmes that influence farmers' perceptions of soil fertility problems and knowledge about management practices, and poverty in general. Market-related factors (production returns relative to the cost of hired labour, physical market access and imperfections in the factor markets) are the most important factors in explaining variations in decisions regarding the use of improved banana management practices. The coefficient on the banana market price relative to the cost of labour was positive and significant in both the probability and the extent of use of all technology equations. This means that raising the output price relative to the cost of labour is likely to have the greatest impact of any single factor.

Infrastructure development and implicitly, physical access to markets increase the probability that a farmer will choose to use mulching, manure and post-harvest residue management practices, all of which are related to soil fertility management. A possible reason for this is that on plantations in the proximity of good roads, increased commercialisation of banana production may accelerate soil fertility depletion, which in turn, stimulates farmers' perception of the soil fertility problem, thus inducing a higher probability of using soil fertility management practices.

Physical access to markets does not seem to be important in decisions regarding the proportion of the banana area treated with organic fertilizers (mulching or manure). Only the extent of use of residue recycling techniques responds to increases in physical access to markets, perhaps because they can be implemented piecemeal and hence spread over time. This could make these practices appear to be less labour-intensive when evaluated within a short-term horizon. The low significance of market access in the scaling-up of the adoption of mulching and manure application may be associated with the high opportunity cost of labour for households with better access to markets in general. Moreover, the supply of organic materials depends on other farm activities, which, in turn, depend on family labour.

The study also indicates that household endowments as in the form of family labour and other production assets (such as livestock and per capita land availability) are critical for the good management of banana plantations, reflecting market imperfections for banana production inputs. Market imperfections are particularly important for practices related to soil fertility management. This is because the organic materials used to mulch and make manure are not sold in markets but produced on the farm as by-products of other farm activities. This causes their supply to be inelastic and dependent on household resources such as landholdings, livestock capital and family labour, which, in turn, influence the activities that produce them.

Land quality attributes also shape decisions regarding the choice and extent of use of banana production management practices. High erosion potential encourages the use of practices related to mulching (mulching with grass or crop residues and residue management) but discourages the use of manure, since the production function shifts inwards when the erosion potential is perceived to be high. This suggests that other techniques that reduce the erosion potential need to be promoted along with manure application, while the positive effect of mulching in curbing the erosion potential should be emphasized in extension messages.

The positive role of information diffusion in banana management decisions is also evident from this study. This result is in line with the observation by Schultz (1975) that if the technology is forever changing to adapt to the changing environment or new components that are introduced, the state of disequilibrium will persist and continued dissemination of information will then be necessary for adoption to occur. Banana management practices are knowledge-based and frequent modifications in management practices to cope with the increase in biotic pressures mean that information dissemination is necessary for their adoption.

10.2.3 Social capital in the banana-growing areas

The study found that across the banana growing regions farmers foster active social participation, though membership in associations was relatively low in the Central region. The most common associations were burial societies and economically oriented associations (i.e. informal credit, agriculture, trade), though less than half of those interviewed report membership in economically oriented associations. The study findings also show that most organizations drew their membership from within the village's geographical boundaries. A possible reason for this is that high transaction costs constrain interactions beyond the village. The social composition of most associations also reflects that of the village, implying a bridging type of social capital when evaluated at the village level.

In addition, rural households also belong to private social networks, which are less formal than associations. Within these social networks, households exchange a variety of economic goods that range from food and labour to consumer durables and cash gifts. Almost every household had transferred part of its income to its social network, while most of them (about 70 %) had also received income from the social network. The least accessed benefit from social networks was zero-interest credit.

10.2.4 Determinants of social capital

The study findings support the prior expectations that there are disparities regarding access to social capital among rural households in Uganda. Households with physical (landholding and livestock) and human capital (education) have better access to associations and private social networks compared to poorer households. It is not clear what lies behind these disparities. This may imply higher returns for the wealthier or barriers to participation for the relatively disadvantaged households. Most of the economically oriented associations that offered immediate benefits in the form of credit required an entry fee, which may inhibit poorer households from joining. Social associations, such as religious and cultural associations, which have comparatively low membership fees, may not offer attractive incentives for the poor, since their immediate need is survival. None of the production assets representing wealth explained membership in agriculturally oriented associations, suggesting that these are neutral to wealth. Most of the agriculture-based associations are initiated with the support (in the form of training, seed or livestock) of external agencies, and entry is normally free.

Other household characteristics found to influence social capital accumulation were the age of the household, gender and initial endowments of social capital. There are gender disparities in social capital accumulation, with men being less likely to participate in social associations than women. However, since the effect of gender was explored by including a dummy of gender for the household head, this result is inconclusive. For, example, the demand for membership in associations may be related to factors unique to female-headed households but not to gender.

The age of the household head also tends to reduce the propensity to accumulate social capital in the form of associations. Research findings further indicate that the initial stock of social capital in the form of a network of relatives is an important source of both "acquired" social network (i.e. network of friends) and social capital in the form of associations. This is because access to a network of relatives generates positive externalities such as trust and reduces risk aversion, both of which encourage social capital accumulation.

The social and economic heterogeneity of the village also has some role to play in social capital accumulation, but the effect depends on the nature and objectives of the associations. Ethnic fragmentation increases the village's rate of participation in socially oriented associations because the village population stratifies into homogenous groups when it comes to participation in socially oriented associations. Economic fragmentation also appears to increase participation in rotating credit and savings associations because these associations tend to be economically homogeneous. Economic fragmentation is an important source of social network intensity because social capital accumulation in the rural areas is economically motivated. However, asymmetries in benefits associated with economic fragmentation tend to discourage household-level accumulation of social capital in the form of associations.

10.3. Implications for policy

The findings of the study have several implications for policy. Although the study has focused on bananas in Uganda, results can be generalized to technology adoption for other crops or to other countries within a similar context.

10.3.1. Implications of social capital as an asset in agricultural development

The results of the study have major implications for incorporating social capital in development projects and technology dissemination strategies. Taken as a whole, the recommendations outline a strategy for incorporating social capital into development interventions in such a way as to make a substantial contribution to agricultural development.

Perhaps the most important implication of the study is that farmers should be encouraged to participate in associations. Through interaction in associations, members can share information from their experiments. Because the information gained comes from other farmers whose opinion the adopter trusts, the potential adopter may skip the stage of experimentation and hence adopt the technology more extensively. Secondly, if more household members participate in associations, they can pool information, so that the influence of the association carries over to the farm, persuading those who manage the banana groves to conform. Furthermore, associations may generate other externalities, such as trust, cooperation and learning how to interact with others, which, in the long run, will have a positive effect on production decisions. The positive interaction between private social networks and the accumulation of social capital in the form of associations also suggests that associations may generate positive externalities in strengthening community networking and hence provide access to resources from others that could be used in agriculture (e.g. borrowing farm implements, land and exchange labour).

Household participation in associations is, however, not enough to make a significant difference on its own, as the structure of participation and the characteristics of the associations concerned also matter. Associations led by individuals with a higher education and livelihood status and who are therefore implicitly more capable of organizing, coordinating and linking the association members with other groups, generate positive externalities in the community that will increase the use of crop management practices. This aspect of social capital was significantly positive for most studies of the management practices. The important implication to be derived from this finding is that when using group-based approaches to intervene in the agricultural development process, there is a need to consider sensitising people as to the role and importance of good leaders. In addition to being well educated and of a higher livelihood status, good leaders need to be trustworthy. This has implications for extension methodology. Extension should not only emphasize the benefits of the technology but also include programmes that encourage community members to form associations with key features that will generate positive externalities for technology adoption in the community.

The relatively low participation rate in each organization also means that incentives and constraints to participation in organizations are likely to be specific to the organization. This implies that while certain organizations may exist in the village, their contribution towards solidarity and collective action for the community's welfare will be limited if people are divided into small groups. Hence, there is a need to encourage organizations with diversified activities while minimizing barriers to participation so as to increase community representation in each organization. This is also important for information pooling and diffusion in the community, which is necessary for the adoption of new agricultural technologies.

The study findings also reveal that while associations may bridge across different social groups, they are limited to the village's geographical boundaries. This implies that associations are likely to be effective in diffusing technologies within a village but limited in their scope as regards the extent to which they can diffuse technologies beyond the village. The implication for extension is that the dissemination of technologies may need to take place at the village level. Unfortunately, this may not be achievable within the current government budget. The formidable challenge is to find out how to stimulate the effective demand among agricultural households for membership in associations beyond village boundaries. There is need to analyse constraints to social interactions beyond the village and identify policies that can broaden the scope of social interactions beyond the village.

The findings of the study also have positive and negative implications for group-based approaches to agricultural extension. An important policy implication in favour of group-based approaches to agricultural extension is that household wealth is unimportant for membership in agriculture-based organizations. This implies that participation in these organizations is wealth-neutral. Thus, promoting agriculturally oriented organizations is less likely to isolate the poor. However, there is a need to sensitise the masses with the aim of making them aware of their mutual interdependence in order to reduce the biases created by formal education in regard to membership in agriculture-based organizations. In addition, most of the agriculture-based associations were externally initiated and more research is needed to understand whether their income-neutrality holds without external influence.

The negative implication is that participation in agriculture-oriented organizations is lower in communities with a high level of ethnic fragmentation. The study shows that an increase in ethnic fragmentation is likely to reduce the propensity to participate in agriculture-based organizations. This could reduce the effectiveness of group-based approaches as a method of agricultural extension, which implies that group-based approaches alone may not be a viable strategy for disseminating technologies in communities with a high degree of ethnic heterogeneity. The same may apply in the case of communities dominated by households with an off-farm production orientation.

The study also reveals that social capital can have positive as well as negative consequences for technology adoption. The negative correlation between participatory norms of decision-making and the adoption of corm paring implies that accounting for social capital in agricultural development projects will need to be based on a thorough analysis of the institutional context, relating this context to the properties of the technology. This could be done as part of the baseline studies and would help in the design of dissemination strategies that are appropriate for the target community as well as the technology being disseminated. The inequalities in social capital accumulation also imply that policies promoting the use of grass-root level associations as an instrument of economic development could widen the gap between rich and poor. Therefore there is a need to design strategies that will encourage poor households and those with a low level of formal education to participate in local organizations. These challenges mean that incorporating social capital in development projects is more of a process than an event, which may demand skills and resources that will be worth investing only if the outcome is a net benefit to the development effort.

10.3.2 Improving the smallholder access to markets

Improving banana farmers' access to markets is another area that, though well recognized, still requires further attention. As the results of the study demonstrate, market-related factors are the most important determinants of banana production management decisions, which implies that banana farmers do respond strongly to market incentives. By implication, government interventions via research and extension in the absence of market incentives would most probably be unsuccessful and would lead to the inefficient use of scarce resources.

Areas where intervention would be useful include investment in rural roads; development of marketing associations on a voluntary basis to reduce the transaction costs in the banana markets; creating an enabling environment for increasing private trader participation; and increasing producer access to market information (e.g. through marketing associations). Investment in the post-harvest processing of bananas to broaden their utilization would also expand the market for bananas and may encourage farmers to invest in production management technologies. The high perishability of bananas precludes storage, implying that the farmers must sell their bananas when mature to avoid losses even when the price of bananas does not cover the cost of production. Consequently, the farmer loses negotiating power when selling his/her bananas. Investment in post-harvest processing should target periods of high production. However, greater commercialisation of banana production would perhaps increase soil depletion. Thus, in addition to improving farmer access to markets, there is a need to address other constraints that, if not dealt with, could render efforts to enhance market access useless.

10.3.3 Implications for banana production management technology

One of the findings of the study is that the use of banana management practices partly depends on household factor endowments (i.e. labour, landholdings and livestock units). This is because of imperfections in the factor markets. Banana management practices are labour-intensive and organic fertilizers (mulching and manure application) are produced on the farm as by-products of other activities, implying that household endowment regarding these inputs is critical for the good management of banana plantations.

However, landholdings are becoming smaller due to population pressure. The opportunity cost of labour may also increase with the general increase in market access. Access to family labour for agriculture is further limited by the current increase in school enrolment following the new policy of universal education in the country and the HIV/AIDS pandemic that has claimed the lives of many young people. Access to livestock is also constrained by poverty in general. Therefore, there is a need to identify and promote banana production technologies that demand less of the farmers' resources. Specifically, there is a need to explore alternative inexpensive sources of fertilizers and to recommend them to farmers. This is particularly important for the farmers operating near paved roads because improvements in market access may be associated with greater soil fertility depletion due to the increased marketing of the fruit to urban centres.

As the study results indicate, a general improvement in access to markets increases the probability of use of soil fertility management practices (mulching and manure application), because of the greater perception of the soil fertility problem that may be associated with the high commercialisation of bananas near good roads, but does not seem to motivate the extent of the use thereof. Instead, farmers rely on the recycling of banana residues to maintain the fertility of the soil in banana plantations. Relying on post-harvest residue to restore soil fertility in these areas is not an adequate method of managing soil fertility in banana plantations, given the high levels of commercialisation.

The results of the study also support the intensification of educational programmes as a means of promoting the use of good management practices. Hence, more support to extension programmes would increase the use of these techniques.

10.4. Limitations of the study and recommendations for future research

This section summarizes some of the limitations of the study and suggests further research.

10.4.1 Additional mechanisms through which social capital influences the adoption of management technologies

The study investigated two mechanisms (information and bilateral transfers) through which social capital may influence the adoption of banana management practices but did not test whether social capital and social learning were actually related. After controlling for bilateral transfers, it was assumed that the remaining effect was attributable to information diffusion. As the results of the study show, information diffusion could not explain all the patterns of correlation in the data, suggesting that there could have been other mechanisms through which institutional social networks worked to influence the use of banana management practices in addition to information diffusion. Future research should therefore test for correlations between these forms of social capital and information acquisition. More research needs to be done to identify alternative mechanisms through which social capital could influence technology adoption. There is also a need for a more detailed study of social capital that examines resource allocation to social capital and the extent to which associations and private social networks are used to overcome market imperfections so as to fully link social capital to other household production processes. Such research might also clarify why poorer households participate less in associations.

10.4.2 Gender and social capital formation

This study explored the effect of gender on social capital accumulation by including a dummy of the gender of the household head. One drawback of the conventional approach is that it does not reveal anything about the behaviour of women who live in male-headed households. Failure to distinguish between women who live in male-headed households and those who live in female-headed households could give rise to a serious omission because their constraints may be different. Therefore, future research should investigate how gender influences participation in associations.

10.4.3 Measurement of social capital

This study relied mainly on quantitative methods, one of the methods used to measure social capital. However, at community level in particular, some issues regarding social capital could be better captured with qualitative methods. Hence, future work should use a combination of these methods.

10.4.4 Scale of the data used to analyse the determinants of social capital

Other limitations are associated with the scale of data collection. The determinants of social capital were investigated on a sub-sample due to budget and logistical constraints, thus limiting the inclusion of some community attributes that might be interesting for policy. In some cases, a lack of variation in the data could have failed to reveal important relationships. Furthermore, social capital is known to be location-specific and future research that has a wide coverage of the rural areas would help to identify more determinants of social capital that are important for policy.

10.4.5 Modeling and estimation approaches

Some orientation as regards the future estimation of the relationship between perceptions, social capital and management decisions can also be derived from the results. The estimation approach adopted in this study is one of the approaches that can be used to analyse the interesting relationships discussed in the conceptual framework. Perceptions depend on physical changes in the environment as well as people’s awareness of such changes. Awareness, in turn, is influenced by social capital. While the approach used in this study is simple and appropriate in its own right, an analysis that employs a two-stage procedure would yield more information on the interaction among these three aspects. An estimation approach that uses an objective measure of perceptions (soil fertility problems and diseases) as explanatory variables in a two-stage estimation procedure would clearly show the influence of social capital in the different stages of the crop management decision-making process. Moreover, an analysis of interactions between different management practices would shed more light on the adoption of the banana management package and its implications for dissemination strategies.

Finally, this research attempted to analyse the factors that influence banana management decisions assuming the homogeneity of banana varieties. Previous studies also identified factors that were important in banana variety choice while taking crop management as a given. Different banana varieties may require different management efforts to be productive. Future research could, therefore, attempt to model these decisions simultaneously rather than sequentially.

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Appendix A. Farmer classification as of banana management practices according to whether the practice is considered to be ancestral or introduced

	Geographical region		
Practice	Central	Eastern	South western
Soil fertility management practices			
Mulch with grass	Ancestral	Introduced	Ancestral
Mulch with crop residues	Ancestral	Ancestral	Ancestral
Kitchen residues	Ancestral	Ancestral	Ancestral
Cattle manure	Ancestral	Introduced	Ancestral
Goat manure	Ancestral	Introduced	Ancestral
Pig manure	Introduced	Introduced	Introduced
Poultry manure	Ancestral	Introduced	Ancestral
Composting	Introduced	Introduced	Introduced
Contour bands	Introduced	Introduced	Introduced
Water bands	Ancestral	Introduced	Introduced
Mat management			
Corm pare	Introduced	Introduced	Introduced
Hot water treatment	Introduced	Introduced	Introduced
Desuckering	Ancestral	Ancestral	Ancestral
Deleafing	Ancestral	Ancestral	Ancestral
Desheathing	Ancestral	Ancestral	Ancestral
Stamping	Ancestral	Ancestral	Ancestral
Chop pseudostem	Introduced	Not known	Introduced
Split pseudostem	Ancestral	Ancestral	Ancestral
Corm removal	Ancestral	Ancestral	Introduced
Weevil trapping	Introduced	Introduced	Introduced

Appendix B. Correlation matrix of explanatory variables used in the analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Weevils	1																						
Altitude	-0.42																						
Aged	-0.05	-0.06																					
Gender	-0.10	0.02	0.06																				
Education	-0.18	-0.16	-0.27	0.14																			
Household size	0.07	-0.15	-0.02	0.01	0.06																		
Dependency ratio	0.04	0.07	0.13	-0.12	0.06	0.31																	
Livestock unit	-0.02	-0.01	0.12	-0.08	0.01	0.21	-0.09																
Per capital land	0.12	-0.02	0.00	0.00	0.05	-0.04	0.04	0.15															
Experience	0.03	0.03	0.01	0.00	0.03	-0.07	0.11	0.05	0.01	0.01													
Number of mats	-0.26	0.10	0.04	0.07	-0.03	0.17	-0.03	0.15	0.07	0.12	0.18												
Distance (Km)	-0.68	-0.38	-0.04	-0.10	-0.24	0.05	0.02	0.01	0.18	0.08	-0.01	-0.14											
Price/wage ratio	0.60	0.29	-0.04	-0.04	0.09	-0.04	-0.02	-0.10	-0.18	-0.07	0.01	0.11	0.50										
Exogenous income	0.06	0.02	0.05	-0.02	0.08	0.10	0.01	-0.03	-0.01	0.01	0.02	-0.01	0.10	0.04									
Membership density	0.30	0.43	-0.15	0.04	0.03	0.28	-0.14	0.07	-0.01	-0.02	-0.07	0.11	0.36	-0.10	-0.01								
Leader heterogeneity	0.20	0.06	0.16	-0.03	0.09	0.14	-0.09	-0.09	0.12	-0.03	0.02	-0.13	0.11	-0.09	0.03	-0.13							
Norms decision make	0.26	0.49	0.12	0.05	0.21	0.05	0.01	-0.09	-0.16	0.01	0.01	0.09	0.30	-0.20	-0.05	-0.13	-0.27						
Cash transfers	0.11	0.06	0.06	-0.10	0.11	0.10	-0.12	-0.02	-0.07	0.05	-0.01	0.12	0.03	-0.05	-0.02	-0.13	0.01	-0.03					
Labour transfers	-0.13	-0.02	0.10	-0.04	-0.08	-0.02	0.01	0.00	0.24	-0.10	-0.04	-0.09	-0.08	0.11	0.00	0.05	-0.07	0.04	0.19				
Other transfers	-0.02	0.01	-0.02	-0.01	0.01	-0.04	-0.02	0.01	0.01	0.01	0.04	-0.07	0.05	-0.02	-0.01	0.01	0.03	0.08	-0.17	-0.08			
Slope of the farm	-0.22	-0.18	-0.06	0.05 4	-0.01	-0.11	-0.05	0.05	-0.01	-0.18	-0.04	-0.00	-0.02	-0.04	0.08	-0.03	0.01	-0.03	-0.07	0.11	0.06	0.01	0.08
Moisture rent	0.12	-0.12	-0.01	-0.00	-0.00	-0.04	-0.00	-0.03	-0.00	-0.04	0.02	-0.04	-0.02	0.00	-0.09	0.08	-0.02	-0.10	0.02	-0.09	-0.00	-0.08	0.03
Drainage conditions	0.16	0.11	-0.01	-0.01	0.11	0.02	0.06	-0.06	-0.06	-0.06	-0.01	0.06	-0.07	0.11	0.06	-0.12	0.10	0.04	0.08	-0.05	0.18	0.01	0.02

Appendix C. Estimation results of factors affecting use of improved banana management practices

Appendix C.1. Probit estimation of factors affecting the probability of using mulching practices

Variable	dF/dx	Std. Err.	z	P>z
Household characteristics (Ω_{HH})				
Age	0.000	0.002	-0.23	0.821
Gender	-0.052	0.057	-0.9	0.368
Education	0.009	0.008	1.2	0.23
Household size	0.017	0.012	1.44	0.151
Dependency ratio	-0.216^	0.122	-1.76	0.078
Livestock unit	0.018	0.016	1.1E+00	0.257
Per capita cultivable land	0.052	0.032	1.61	0.107
Income from private assets	1.2E-06	1.6E-06	0.73	0.464
Physical farm characteristics (Ω_F)				
Elevation	0.026	0.098	0.26	0.793
Poor drainage conditions	-0.023	0.057	-0.4	0.687
Moisture retention capacity	-0.138*	0.075	-1.96	0.05
Slope of the farm	0.037	0.070	0.55	0.583
Age of the banana plantation	-0.002	0.002	-0.7	0.486
Number of banana mats	0.0001*	0.0001	2.01	0.044
Market factors (Ω_M)				
Distance from paved roads	-0.011*	0.005	-2.28	0.023
Price/labour wage ratio	3.080**	1.037	2.94	0.003
Information diffusion parameters (Ω_D)				
Relative experience	0.814**	0.160	4.99	0.000
Exposure	-0.017	0.068	-0.25	0.799
Extension contact	0.015	0.019	0.82	0.415
Social capital (Ω_{SS})				
Household membership density	0.021	0.036	0.59	0.552
Leader heterogeneity	0.057	5.1E-02	1.1E+00	0.261
Participatory decision-making norms	0.312**	7.9E-02	4.0E+00	0.000
Net labour transfers	-4.1E-06^	2.3E-06	-1.82+00	0.069
Net cash transfers	5.5E-07	4.8E-07	1.1E+00	0.255
Net transfers durables	3.4E-07	1.3E-06	0.27	0.79
Observed probability	6.99E-01			
Predicted probability	7.93E-01			
Number of observations	312			
LR chi2(25)	115.54			
Prob > chi2	0			
Pseudo R2	0.303			
Log likelihood =	-133.159			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix C.2. Probit estimation of factors affecting the probability of using manure application

Variable	dF/dx	Std. Err.	z	P>z
Household characteristics (Ω_{HH})				
Age	-0.006*	0.002	-2.33	0.02
Gender	-0.024	0.072	-0.33	0.743
Education	0.008	0.009	0.88	0.378
Household size	0.018	0.015	1.2	0.228
Dependency ratio	-0.004	0.169	-0.03	0.98
Livestock unit	0.109**	0.022	4.89	0.000
Per capita cultivable land	0.023	0.022	1.06	0.288
Income from private assets	8.7E-07	1.47E-06	0.59	0.554
Physical farm characteristics (Ω_F)				
Elevation	-0.036	0.123	-0.29	0.77
Poor drainage conditions	0.148*	0.074	1.99	0.047
Moisture retention capacity	0.071	0.087	0.83	0.408
Slope of the farm	-0.160^	0.086	-1.85	0.064
Age of the banana plantation	-0.003	0.003	-1.21	0.228
Number of banana mats	0.000	0.000	0.94	0.348
Market factors (Ω_M)				
Distance from paved roads	-0.007	0.006	-1.22	0.224
Price/labour wage ratio	2.847*	1.261	2.26	0.024
Information diffusion parameters (Ω_D)				
Relative experience	1.280**	2.54E-01	5.07	0.000
Exposure	0.099	0.086	1.14	0.254
Extension contact	0.020	0.017	1.18	0.238
Social capital (Ω_{SS})				
Household membership density	0.047	0.045	1.04	0.297
Leader heterogeneity	0.205**	0.068	3.02	0.003
Participatory decision-making norms	0.261**	1.01E-01	2.57	0.01
Net labour transfers	2.41E-06	2.91E-06	0.83	0.408
Net cash transfers	6.55E-07	6.02E-07	1.09	0.276
Net transfers durables	4.0E-06**	1.58E-06	2.53	0.012
Observation. P	0.426			
Predicted.	0.413			
Number of observations	312			
LR chi2(25)	124			
Prob > chi2	0.000			
Pseudo R2	0.2913			
Log likelihood =	-150.860			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix C.3. Probit estimation of factors affecting the probability of using desuckering

Variable	dF/dx	Std. Err.	Z	P>z
Household characteristics (Ω_{HH})				
Age	-0.004	0.003	-1.380	0.169
Gender	-0.157^	0.087	-1.800	0.072
Education	0.013	0.011	1.130	0.258
Household size	0.019	0.017	1.100	0.270
Dependency ratio	-0.031	0.196	-0.160	0.873
Livestock unit	-0.048*	0.025	-1.950	0.051
Per capita cultivable land	-0.002	0.020	-0.090	0.929
Income from private assets	6.8E-07	1.3E-06	0.510	0.612
Physical farm characteristics (Ω_F)				
Elevation	0.851**	0.035	7.470	0.000
Poor drainage conditions	-0.026	0.093	-0.280	0.783
Moisture retention capacity	-0.076	0.112	-0.680	0.500
Slope of the farm	0.137	0.112	1.190	0.236
Age of the banana plantation	-0.003	0.004	-0.660	0.507
Number of banana mats	-5.7E-06	0.0002	-0.04	0.971
Market factors (Ω_M)				
Distance from paved roads	-0.016*	0.008	-1.990	0.046
Price/labour wage ratio	3.143*	1.593	1.970	0.048
Information diffusion parameters (Ω_D)				
Relative experience	0.172^	0.097	1.780	0.076
Exposure	0.326**	0.096	3.200	0.001
Extension contact	-0.007	0.020	-0.320	0.750
Social capital (Ω_{SS})				
Household membership density	-0.075	0.053	-1.430	0.152
Leader heterogeneity	0.240**	0.074	3.240	0.001
Participatory decision-making norms	0.138	0.117	1.180	0.237
Net labour transfers	-2.4E-06	2.0E-06	-1.22	0.222
Net cash transfers	-2.4E-07	8.8E-07	-0.27	0.789
Net transfers durables	2.2E-07	1.6E-06	0.14	0.889
obs. P	0.433			
pred.	0.488			
Number of obs	312.000			
LR chi2(25)	210.210			
Prob > chi2	0.000			
Pseudo R2	0.493			
Log likelihood =	-108.322			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix C.4. Probit estimation of factors affecting the probability of using corm pare

Variable	dF/dx	Std. Err.	Z	P>z
Household characteristics (Ω_{HH})				
Age	-0.001	0.002	-0.730	0.466
Gender	0.004	0.047	0.100	0.924
Education	0.027*	0.007	3.990	0.000
Household size	0.013	0.010	1.270	0.202
Dependency ratio	0.006	0.110	0.060	0.953
Livestock unit	0.003	0.014	0.230	0.814
Per capita cultivable land	0.013	0.014	0.910	0.365
Income from private assets	-2.2E-07	7.9E-07	-0.28	0.782
Physical farm characteristics (Ω_F)				
Elevation	0.215*	0.122	2.04	0.042
Poor drainage conditions	-0.082^	0.047	-1.66	0.098
Moisture retention capacity	0.054	0.061	0.93	0.353
Slope of the farm	-0.111^	0.070	-1.73	0.084
Age of the banana plantation	-0.002	0.002	-1.11	0.265
Number of banana mats	-8.2E-05	1.0E-7	-0.81	0.418
Market factors (Ω_M)				
Distance from paved roads	0.016**	0.004	3.88	0.000
Price/labour wage ratio	2.939**	0.870	3.33	0.001
Information diffusion parameters (Ω_D)				
Relative experience	0.098*	0.049	1.99	0.047
Exposure	0.286**	0.061	4.81	0.000
Extension contact	0.016	0.012	1.28	0.202
Social capital (Ω_{SS})				
Household membership density	-0.036	0.035	-1.01	0.312
Leader heterogeneity	0.092*	0.048	1.94	0.052
Participatory decision-making norms	-0.256**	0.063	-3.98	0.000
Net labour transfers	8.9E-07	1.35E-06	0.66	0.509
Net cash transfers	3.3E-07	5.59E-07	0.59	0.558
Net transfers durables	5.6E-07	9.53E-07	0.58	0.559
obs. P	0.229			
Pred.	0.145			
Number of obs	310.000			
LR chi2(25)	113.730			
Prob > chi2	0.000			
Pseudo R2	0.341			
Log likelihood =	-109.949			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix C.5. Probit estimation of factors affecting the probability of using Post harvest residue management practices

Variable	dF/dx	Std. Err.	z	P>z
Household characteristics (Ω_{HH})				
Age	0.000	0.001	0.440	0.660
Gender	0.027	0.024	1.140	0.253
Education	0.008*	0.004	2.430	0.015
Household size	0.007	0.005	1.460	0.145
Dependency ratio	-0.029	0.053	-0.560	0.578
Livestock unit	-0.016)**	0.007	-2.690	0.007
Per capita cultivable land	0.041*	0.019	2.270	0.023
Income from private assets	-5.0E-07	4.93E-07	-1.06	0.291
Physical farm characteristics (Ω_F)				
Elevation	0.093*	0.034	2.170	0.030
Poor drainage conditions	0.003	0.024	0.110	0.910
Moisture retention capacity	0.018	0.026	0.640	0.523
Slope of the farm	-0.015	0.028	-0.500	0.617
Age of the banana plantation	0.001	0.001	0.500	0.616
Number of banana mats	1.5E-06	4.2E-6	0.04	0.971
Market factors (Ω_M)				
Distance from paved roads	-0.007**	0.002	-3.430	0.001
Price/labour wage ratio	0.885*	0.465	2.020	0.044
Information diffusion parameters (Ω_D)				
Relative experience	0.008	0.026	0.300	0.768
Exposure	0.014	0.028	0.500	0.617
Extension contact	0.007	0.007	0.950	0.344
Social capital (Ω_{SS})	0.004	0.016	0.240	0.811
Household membership density	0.005	0.022	0.200	0.840
Leader heterogeneity	0.041	0.031	1.400	0.161
Participatory decision-making norms	7.7E-07	6.7E-07	1.22	0.223
Net labour transfers	-5.5E-08	2.7E-07	-0.25	0.801
Net cash transfers	-4.9E-07	5.2E-07	-0.93	0.351
obs. P	0.850			
pred.	0.950			
Number of obs	341.000			
LR chi2(25)	89.200			
Prob > chi2	0.000			
Pseudo R2	0.310			
Log likelihood =	-99.283			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix. C.6. OLS Regression of the extent of use of mulching practice

Variable	Coefficient.	Std. Err.	t	P>t
Household characteristics (Ω_{HH})				
Age	0.000	0.001	-0.15	0.881
Gender	0.054^	0.031	1.72	0.087
Education	0.009	0.004	2.15	0.033
Household size	0.007	0.007	1.06	0.291
Dependency ratio	0.134	0.084	1.6	0.112
Livestock unit	-1.0E-03	8.6E-03	-0.12	0.905
Per capita cultivable land	0.020*	0.009	2.24	0.026
Income from private assets	3.8E-07	5.0E-07	0.76	0.449
Physical farm characteristics (Ω_F)				
Elevation	-0.111^	0.062	-1.79	0.075
Poor drainage conditions	-0.011	0.034	-0.34	0.737
Moisture retention capacity	-0.001	0.043	-0.01	0.989
Slope of the farm	0.121**	0.038	3.19	0.002
Age of the banana plantation	0.000	0.001	0.39	0.696
Number of banana mats	-0.0001**	5.3E-05	-2.72	0.007
Market factors (Ω_M)				
Distance from paved roads	0.003	0.003	1.17	0.244
Price/labour wage ratio	1.648**	0.571	2.89	0.004
Information diffusion parameters (Ω_D)				
Relative experience	0.037	0.103	0.36	0.721
Exposure	0.037	0.039	0.96	0.337
Extension contact	-0.004	0.007	-0.6	0.551
Social capital (Ω_{SS})				
Household membership density	4.5E-02*	1.84E-02	2.45	0.015
Leader heterogeneity	9.6E-02**	3.15E-02	3.06	0.003
Participatory decision-making norms	-2.8E-02	5.91E-02	-0.48	0.635
Net labour transfers	1.4E-06	8.81E-07	1.59	0.113
Net cash transfers	1.0E-08	2.72E-07	0.04	0.97
Net transfers durables	-6.1E-07	5.59E-07	-1.1	0.274
Millmuc	0.028	0.062121	0.45	0.653
_cons	-0.542	0.381	-1.43	0.156
Number of observations	213			
F(26, 186)	5.380			
Prob > F	0.000			
R-squared	0.429			
Adj R-squared	0.349			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix C.7. Second stage Heckman regression of the extent of use of manure Application

Variable	Coefficient.	Std. Err.	t	P>t
Household characteristics (Ω_{HH})				
Age	-0.004^	0.002	-1.83	0.071
Gender	-0.004	0.044	-0.09	0.932
Education	0.005	0.006	0.8	0.428
Household size	0.021^	0.011	1.89	0.062
Dependency ratio	0.039	0.112	0.35	0.726
Livestock unit	0.068*	0.029	2.36	0.02
Per capita cultivable land	0.009	0.012	0.75	0.453
Income from private assets	1.7E-06**	5.7E-07	2.93	0.004
Physical farm characteristics (Ω_F)				
Elevation	0.056	0.093	0.6	0.547
Poor drainage conditions	0.062	0.061	1.02	0.31
Moisture retention capacity	0.049	0.053	0.91	0.363
Slope of the farm	-0.077	0.064	-1.19	0.236
Age of the banana plantation	0.000	0.002	-0.12	0.903
Number of banana mats	-0.0002*	8.7E-05	-2.36	0.02
Market factors (Ω_M)				
Distance from paved roads	0.002	0.004	0.49	0.624
Price/labour wage ratio	1.487	0.950	1.57	0.121
Information diffusion parameters (Ω_D)				
Relative experience	0.409	0.349	1.17	0.245
Exposure	0.147*	0.061	2.42	0.017
Extension contact	0.033**	0.012	2.83	0.006
Social capital (Ω_{SS})				
Household membership density	-0.027	0.028	-0.98	0.329
Leader heterogeneity	0.204**	0.068	3.02	0.003
Participatory decision-making norms	0.124	0.105	1.18	0.241
Net labour transfers	5.1E-06**	1.8E-06	2.86	0.005
Net cash transfers	1.6E-07	3.7E-07	0.42	0.676
Net transfers durables	8.7E-07	1.4E-06	0.63	0.528
Millman	-0.268^	0.143	-1.87	0.065
Constant	-1.224	0.742	-1.65	0.102
Number of obs	128			
F(26, 101)	3.39			
Prob > F	0.00^			
R-squared	0.466			
Adj R-squared	0.329			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix C.8. OLS Regression of the extent of use of Post harvest residue management practices

Variable	Coefficient.	Std. Err.	t	P>t
Household characteristics (Ω_{HH})				
Age	-0.003	0.002	-1.64	0.102
Gender	0.044	0.049	0.9	0.367
Education	0.013	0.007	1.99	0.047
Household size	0.015	0.011	1.41	0.159
Dependency ratio	-0.034	0.110	-0.31	0.756
Livestock unit	-0.014	0.016	-0.87	0.384
Per capita cultivable land	0.038**	0.014	2.7	0.007
Income from private assets	-1.8E-06	1.7E-06	-1.07	0.284
Physical farm characteristics (Ω_F)				
Elevation	0.368**	0.084	4.4	0.000
Poor drainage conditions	0.033	0.051	0.66	0.51
Moisture retention capacity	0.016	0.057	0.28	0.78
Slope of the farm	0.173**	0.056	3.09	0.002
Age of the banana plantation	9.3E-05	8.3E-05	1.12	0.266
Number of banana mats	0.003	0.002	1.44	0.152
Market factors (Ω_M)				
Distance from paved roads	-0.025**	0.004	-5.92	0.000
Price/labour wage ratio	3.118**	0.857	3.64	0.000
Information diffusion parameters (Ω_D)				
Relative experience	0.230**	0.054	4.29	0.000
Exposure	0.012	0.059	0.21	0.833
Extension contact	0.005	0.012	0.45	0.654
Social capital (Ω_{SS})				
Household membership density	-0.040	0.030	-1.32	0.187
Leader heterogeneity	-0.016	0.050	-0.32	0.749
Participatory decision-making norms	-0.009	0.073	-0.13	0.9
Net labour transfers	2.0E-06	2.1E-06	0.92	0.361
Net cash transfers	-3.1E-07	4.4E-07	-0.7	0.486
Net transfers durables	-1.1E-06	1.0E-06	-1.07	0.287
Mills ratio				
Constant	0.458	0.539	0.85	0.396
Number of obs	289			
F(25, 263)	12.12			
Prob > F	0.000			
R-squared	0.535			
Adj R-squared	0.491			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix D: Estimation results of factors influencing social capital accumulation

Appendix D.1. Probit estimation of the factors influencing membership in at least one associations

Variables	Marginal effects	Standard Errors	Z	P>z
Age of the household head	-0.006^	0.007	-1.8	0.072
Number of household members below 15 years of age	-0.005	0.028	-0.29	0.775
Number of household members aged between 16 and 50 years of age	-0.088	0.058	-1.2	0.229
Number of household members aged above 50 years of age	-0.166	0.139	0.15	0.885
Gender of the household head	-0.167	0.147	-1.44	0.151
Education of the household head	0.035*	0.018	1.98	0.054
Landholding in 2001	0.049*	0.024	1.97	0.049
Livestock capital in 2001	0.063	0.049	1.43	0.152
Number of years in the village	0.002	0.004	0.54	0.588
Distance from home to nearest post office	-0.049	0.059	-0.71	0.48
Number of relatives	0.009	0.017	0.56	0.572
Farm production orientation	0.066	0.146	0.28	0.777
Number of NGOs operating in the village	-0.017	0.083	-0.06	0.952
Education heterogeneity in the village in 2001	-0.071	0.067	-1.34	0.181
Ethnic fragmentation in the village 2001	0.620	0.504	1.09	0.275
Observed probability	0.539			
Predicted probability	0.561			
Likelihood ratio chi sq (15)	26.15			
Probability chi sq	0.037			
Pseudo R2	0.213			
Log likelihood =	-48.34			

** Significant at 1%, * significant at 5%, ^ significant at 10 %

Appendix D.2. Probit estimation of the factors influencing membership in social associations

Variables	Marginal Effects	Standard Errors	z	P>z
Age of the household head	-0.014*	0.006	-2.33	0.02
Number of household members below 15 years of age	0.028	0.024	1.44	0.15
Number of household members aged between 16 and 50 years of age	-0.121*	0.058	-2.23	0.026
Number of household members aged above 50 years of age	-0.014	0.140	-1.23	0.219
Gender of the household head	-0.315*	0.171	-1.98	0.047
Education of the household head	-0.001	0.015	-0.19	0.845
Landholding in 2001	0.030*	0.018	1.97	0.049
Livestock capital in 2001	0.073*	0.035	2.25	0.024
Number of years in the village	0.004	0.0040	0.62	0.538
Distance from home to nearest post office	-0.037	0.041	-0.93	0.351
Number of relatives	0.001	0.011	0.29	0.77
Farm production orientation	0.237*	0.099	1.99	0.046
Number of NGOs operating in the village	0.096	0.068	1.25	0.212
Education heterogeneity in the village in 2001	-0.055	0.059	-0.69	0.489
Ethnic fragmentation in the village 2001	1.042**	0.451	2.51	0.012
Observed probability	0.311			
Predicted probability	0.238			
Likelihood ratio chi sq (15)	31.7			
Probability chi sq	0.0071			
Pseudo R2	0.284			
Log likelihood =	-39.9505			

** Significant at 1%, * significant at 5%

Appendix D.3. Probit estimation of the factors influencing membership in Agricultural-oriented associations

Variables	Marginal effects	Standard Errors	z	P>z
Age of the household head	0.002	0.004	0.05	0.958
Number of household members below 15 years of age	0.021^	0.016	1.54	0.124
Number of household members aged between 16 and 50 years of age	-0.002	0.034	0.05	0.961
Number of household members aged above 50 years of age	-0.052	0.085	-0.23	0.816
Gender of the household head	0.043	0.079	0.56	0.575
Education of the household head	0.020^	0.011	1.66	0.097
Landholding in 2001	0.025	0.016	1.58	0.114
Livestock capital in 2001	-0.027	0.021	-1.36	0.175
Number of years in the village	-0.001	0.003	-0.7	0.482
Distance from home to nearest post office	-0.001	0.021	-0.05	0.961
Number of relatives	0.035**	0.012	2.94	0.003
Farm production orientation	0.165*	0.065	2.14	0.033
Number of NGOs operating in the village	0.009	0.059	0.25	0.804
Education heterogeneity in the village in 2001	0.024	0.045	0.83	0.404
Ethnic fragmentation in the village 2001	-0.486	0.314	-1.67	0.094
Observed probability	0.189			
Predicted probability	0.104			
Likelihood ratio chi sq (15)	33.92			
Probability chi sq	0.0035			
Pseudo R2	0.3889			
Log likelihood =	-26.652743			

** Significant at 1%, * significant at 5% and ^ significant at 10%.

Appendix D.4. Probit estimation of the factors influencing membership in revolving saving and credit association

Variables	Marginal effects	Standard Errors	z	P>z
Age of the household head	-0.005*	0.002	-2.16	0.031
Number of household members below 15 years of age	-0.010	0.011	-0.66	0.508
Number of household members aged between 16 and 50 years of age	-0.022	0.019	-1.42	0.156
Number of household members aged above 50 years of age	0.037	0.046	1.26	0.208
Gender of the household head	-0.062	0.081	-1	0.318
Education of the household head	0.015**	0.008	1.97	0.049
Landholding in 2001	0.002	0.006	0.41	0.682
Livestock capital in 2001	0.019*	0.010	1.88	0.061
Number of years in the village	-0.001	0.002	-1.31	0.191
Distance from home to nearest post office	0.002	0.007	0.47	0.638
Number of relatives	-0.001	0.004	0.09	0.924
Farm production orientation	0.084^	0.044	1.8	0.071
Number of NGOs operating in the village	0.056*	0.031	2.13	0.033
Education heterogeneity in the village in 2001	0.049*	0.031	2.25	0.025
Ethnic fragmentation in the village 2001	-0.098	0.194	-0.61	0.54
Observed probability	0.144			
Predicted probability	0.038			
Likelihood ratio chi sq (15)	22.04			
Probability chi sq	0.1067			
Pseudo R2	0.297			
Log likelihood =	-26.14			

** Significant at 1%, * significant at 5% and ^ significant at 10%.

Appendix D.5. Poisson estimation of factors affecting the intensity of membership in associations at the household level

Variable	Coefficient .	Std. Err.	z	P>z
Age of household head	-0.029**	0.014	-2.8	0.005
Number of household members below 15 years of age	0.023	0.047	0.17	0.868
Number of household members aged between 16 and 50 years of age	-0.097	0.107	-0.98	0.325
Number of household members aged above 50 years	0.090	0.293	0.14	0.892
Gender of household head	-0.357	0.308	-1.14	0.253
Education of household head	0.075**	0.0307	2.7	0.007
Landholding in 2001	0.063*	0.034	1.99	0.047
Livestock capital in 2001	0.034	0.047	0.87	0.383
Number of years in the village	0.001	0.009	0.17	0.864
Distance from home to nearest post office	-0.182	0.158	-1.2	0.229
Number of relatives	0.027*	0.014	1.94	0.053
Farm production orientation	0.430	0.262	1.6	0.11
Number of NGOs operating in the village	0.191	0.151	1.21	0.226
Educational heterogeneity in the village in 2001	-0.301*	0.138	-2.48	0.013
Ethnic fragmentation in the village 2001	-0.551	0.803	-0.62	0.538
_Constant	1.960	1.006	2.2	0.028
Number of observations	90			
LR chi sq (15)	76.19			
Probability chi sq	0.00			
Pseudo R2	0.247			
Log likelihood	-116.300			

Appendix D.6. Negative binomial estimation of factors affecting the intensity of private social networks at the household level

Variable	Coefficient.	Std. Err.	z	P>z
Age of household head	-0.002	0.008	0.2	0.844
Number of household members below 15 years of age	-0.058*	0.033	-2.34	0.019
Number of household members aged between 16 and 50 years of age	0.107	0.073	1.09	0.275
Number of household members aged above 50 years	0.302**	0.176	2.67	0.007
Gender of household head	0.211	0.183	1.26	0.207
Education of household head	0.103**	0.021	5.32	0
Landholding in 2001	-0.019	0.025	-0.61	0.544
Livestock capital in 2001	-0.048	0.035	-1.48	0.139
Number of years in the village	-0.004	0.005	-0.34	0.737
Distance from home to nearest post office	-0.014	0.029	-0.27	0.789
Number of relatives	0.007	0.012	0.39	0.696
Farm production orientation	0.246^	0.171	1.79	0.073
Number of NGOs operating in the village	-0.060	0.107	-0.88	0.376
Educational heterogeneity in the village in 2001	-0.397**	0.085	-4.87	0.000
Ethnic fragmentation in the village 2001	-0.269	0.593	-0.06	0.951
_Constant	3.784**	0.624	6.07	0
Number of observations	89			
LR chi sq (15)	46.11			
Probability chi sq	0.0001			
Pseudo R2	0.067			
Log likelihood	-341.090			
Likelihood-ratio test of alpha=0 Chi sq 2(01)	0.000			