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Social Capital as a Determinant of Farm-level Sustainable Land Management Adoption

– A case study of smallholder farmers in northern Benin

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Abstract

In many developing countries high rates of farmland degradation contribute to the low performance of smallholder agriculture and pose serious policy challenges. Despite promotion efforts by government and non-governmental organizations adoption of improved agricultural production technologies remains low in Sub-Saharan Africa. This thesis examines the role of social capital in enhancing the adoption of sustainable land management (SLM) though smallholder farmers in northern Benin. In particular, the thesis focuses on how group membership, market and family networks, participation in extension programmes and the quality of social capital influences the adoption and extent of adoption of SLM practices. The analysis of household's adoption behaviour is based on an interdisciplinary conceptual framework and cross-sectional data collected though a household survey among 200 randomly selected households in two villages in northern Benin. Exploratory principal component analysis is used to categorise and combine the 14 considered SLM practices into components. Linear regression models are applied to analyses the effect of social capital on the adoption of the five SLM components and an ordered probit model is used to examine the effect on the extent of SLM adoption. The results underscore the importance of social capital especially identifying, linking, bridging and the quality of social capital. The study demonstrates that households' adoption decisions are determined by the perception of the land quality, location, ethnicity, participation in development projects, farm size, livestock ownership as well as access to credit and extension service. Policies that target SLM and are aimed at organizing farmers into associations, improving market networks, adjusting extension services to local societies and promoting awareness can increase the uptake of SLM in smallholder systems and are therefore means to food security and poverty reduction.

Keywords: sustainable land management, social capital, agricultural technology adoption, principal component analysis, ordered probit model, Benin

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III. List of Abbreviations

FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GIZ	German Corporation for International Cooperation
IASS	Institute for Advanced Sustainability Studies
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
KMO	Kaiser-Meyer-Olkin
LADA	Land Degradation Assessment in Drylands
LDN	Land degradation neutrality
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary least square
PC	Principal component
PCA	Principal component analysis
ProSOL	Soil Protection and Rehabilitation for Food Security
SDG	Sustainable Development Goal
SLM	Sustainable land management
SURE	Seemingly unrelated regression estimation
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification

1 Introduction

Can social capital facilitate the adoption and use of sustainable land management (SLM) practices, which help to reduce land degradation and are therefore means to food security and poverty reduction? The present thesis attempts to answer this question by examining the impact of social capital on the SLM adaption behaviour of rural households in northern Benin.

1.1 Problem statement

Land degradation[1] hinders sustainable development. It is a serious problem on a global scale that particularly impacts the rural poor of low and middle-income countries (FAO, 2017). In the case of Benin, 1.8 million people were living on degrading agricultural land in 2010 corresponding to an increase of 37 % in a decade (Global Mechanism of the UNCCD, 2018). According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (IPBES, 2018) the most extensive global direct driver of land degradation is the rapid expansion and unsustainable management of croplands and grazing lands, causing significant loss of biodiversity and ecosystem services. However, the livelihoods of the majority of the rural poor depend on the ecosystem services provided by their land (Adhikari & Hartemink, 2016). Hence in many developing countries land degradation is a serious threat to agriculture productivity and food security. This applies for Benin where agriculture accounts for about 25 % of Gross Domestic Product (GDP) and 45-55 % of employment (World Bank, 2018). The effects of land degradation are far-reaching and go beyond the local and regional level, leading to global consequences such as migration, food insecurity and climate change (IPBES, 2018). For Benin alone, the annual cost of land degradation is estimated at 490 million US dollar which equates to 8 % of the country's GDP (Global Mechanism of the UNCCD, 2018). However, according to a report by Nkonya, Mirzabaev, & Von Braun (2016) the cost of taking action against land degradation is much lower than the cost of inaction. In view of target 15.3 of the Sustainable Development Goals (SDGs) which strives to achieve a land degradation neutral world by 2030 and puts an emphasis on the restoration of degraded land Benin has set its national voluntary Land Degradation Neutrality (LDN) targets. The aim is to achieve LDN by 2030 through the restoration of 1.25 million hectares of degraded land, while increasing efforts to avoid further degradation (Global Mechanism of the UNCCD, 2018). SLM could be a promising strategy for achieving this target. However, the adoption rate of SLM practices has been said to be low (Wossen, Berger, & Di Falco, 2015). Although SLM practices entail many benefits, they present two major challenges for their successful distribution: length of the payback period and externalities. That is, the positive effects derived from SLM are most often only noticeable after several years of implementation (Global Environment Facility, 2018). Secondly, while the additional costs and the necessary investments associated with the adoption of SLM practices accrue at the farm level, benefits of SLM are gained by the farmer as well as by the society as a whole (Branca, McCarthy, Lipper, & Jolejole, 2011; Wollni, Lee, & Thies, 2010), namely in the form of climate change mitigation (Branca, Lipper, McCarthy, & Jolejole,

[1] In this thesis land degradation is defined according to the definition by the Land Degradation Assessment in Drylands (LADA) project which describes land degradation as: "the reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for its beneficiaries" (Bunning, McDonagh, & Rioux, 2016).

2013) and food security (Yimer, 2015). Hence the challenge of achieving SLM comes down to the short-term profit over long-term sustainability as well as the public good dilemma. While there is a variety of literature that examines factors influencing agricultural technology adoption, there is no clear understanding of the means to overcome these constraints and little attention has been paid to the role of social capital in the context of SLM adoption. However, given that the benefits derived from SLM are partly public goods and from an individual's perspective the barriers to adaptation are high, social capital is likely to play an important role when it comes to strategies to encourage SLM (Wollni et al., 2010).

1.2 Purpose

In order to develop policy strategies that will enhance sustainability of agricultural production systems, detailed information on factors influencing household's SLM adoption decision are required. Based on the idea that social capital may allow smallholders to overcome some of the constraints related to the implementation of SLM this thesis aims to answer the research question of whether social capital affects the adoption and extent of SLM among smallholder farmers. The objective of this thesis is to analyse the effects of social capital on the adoption and the extent of adoption of SLM practises by smallholder farmers in two villages in northern Benin, where land degradation is a severe problem. To this end the subobjectives are threefold: The study seeks to ascertain whether different forms of social capital affect (1) the adoption of SLM and (2) the extent of SLM application. The research further aims to analyse whether (3) the quality of social capital matters for farmers' adoption decision. Accordingly, three main hypotheses about the relationship of social capital to SLM adoption are defined:

H_1: Social capital in the form of membership in village groups, market network, family network and participation in the Soil Protection and Rehabilitation for Food Security (ProSOL) project enhances the adoption of SLM practices.

H_2: Social capital in the form of membership in village groups, market network, family network and participation in the ProSOL project positively influences the number of adopted SLM practices.

H_3: The quality of social capital influences the adoption and level of use of SLM, so that negative social capital[2] has a negative effect on the adoption and the extent of adoption of SLM technologies.

These hypotheses are tested using linear regression and ordered probit model to cross-sectional data collected through a household survey among randomly selected smallholder farmers in two villages in northern Benin.

This study contributes to ongoing efforts to promote SLM by providing policymakers with information on how social structures affect the adoption of SLM among smallholders. This is of political relevance especially with regard to SDG target 15.3 but will also contribute to the achievement of multiple other SDG targets including those relating to climate change mitigation and adaptation, biodiversity conservation, ecosystem restoration, food and water security, disaster risk reduction, food security and poverty reduction.

[2] Social capital generating negative outcomes is generally called as negative social capital.

1.3 Outline

The rest of the thesis is structured as follows: Section 2 examines the literature on SLM and the theory behind agricultural technology adoption and social capital. Section 3 presents the theoretical model and conceptual framework and describes the data. It follows the specification of the empirical models and the methodological approach. Section 4 and 5 present and discuss the results respectively. The last section draws policy recommendations.

2 Literature review

The following section explains SLM and reviews the existing literature on conceptual models, factors influencing adoption as well as the concept of social capital and its role in technology adoption. Finally, the gap in the literature is identified.

2.1 Sustainable land management

TerrAfrica (Liniger, Mekdaschi, Hauert, & Gurtner, 2011) and FAO (2017) describe SLM as the adoption of land-use systems or land management practices that "enable land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources". This definition shows that the primary goal of SLM is threefold: (1) maintaining ecosystem functions and services while (2) supporting human wellbeing and (3) ensuring economic productivity. The idea of the simultaneous fulfilment of these three goals is in line with the three dimensions of sustainability. The first goal addresses the environmental dimension of sustainable development. It claims that SLM practices are environmental friendly, aim at improving ecosystem functions and services, reduce current land degradation, improve biodiversity and increase resilience to climate variation and change (Liniger et al., 2011). Socially, SLM supports sustainable livelihoods by conserving or raising soil productivity, thus improving food security and reducing poverty, both at household and national levels. Economically, SLM ensures long-term sustainable land productivity and hence pays back investments made by land users, communities or governments in the long-run. SLM is a useful tool for arable farmers and livestock keepers alike, as well as for small-scale subsistence and large-scale commercial farmers (Liniger et al., 2011).

To capture the whole spectrum of the effects of SLM, 14 different sustainable farming practices have been considered in this study: mineral fertilizer, composting, animal manure, anti-erosion measures, agroforestry, fallow, burying crop residues, crop rotation, intercropping of cereal and legume, planting pigeon pea, mucuna, stylosanthes guianensis, aeschynomene histrix and fodder crops. These practices have advantages such as improved physical properties of the soil, soil and water conservation, improved soil fertility, supply of plant nutrients and closing the nutrient cycle, suppression of weed, permanent cover of the soil, carbon sequestration and hence increase the yields of crops and animal products. While some of these practices are cost-intensive such as mineral fertiliser, others are more labour intensive, such as burying crop residues, composting, using animal manure and creating anti-erosion measures. Other practices require a lot of knowledge such as intercropping, crop rotation and planting pigeon pea, mucuna, stylosanthes guianensis and aeschynomene histrix.

2.2 Conceptual models for technology adoption

Four main types of conceptual models can be found in the literature explaining the decision of a smallholder farmer to adopt new technology: economic constraints models, technology diffusion models, adopter perception models and behavioural models. These theories form the basis of the conceptual framework for this study and are therefore briefly explained whilst also pointing out their advantages and shortcomings:

The *economic constraints model* assumes that resource endowments are unevenly distributed across farm households and hence consider economic and institutional conditions as important determinants of technology adoption (Adesina & Zinnah, 1993; Negatu & Parikh, 1999). Potential economic constraints include natural resource endowments (e.g., land), lack of capital, learning costs associated with the implementation of a new technology, and risk attitude (Foltz, 2003). The underlying assumption of this paradigm is that technology adoption is driven by the utility or profit maximising behaviour of the farmer. On the one hand this approach benefits from the explanation that profitability motivates innovation or adoption (Posthumus, Gardebroek, & Ruben, 2010). On the other hand this approach falls short as smallholders in developing countries often opt for profits below its maximum, since nonfinancial variables (e.g., leisure, traditions, environmental protection) also play an important role in their decision making (Ellis, 1993).

The *innovation-diffusion-adoption* models follow from the initial innovation-diffusion theory of Rogers (1995). According to this paradigm, the characteristics of a technology and the access to information are key factors determining adoption decisions. According to Rogers (2002), the features that determine an innovation's rate of adoption are relative advantage, compatibility, complexity, trialability, and observability. Assuming the innovation fulfils these requirements, the problem of technology adoption is reduced to communicating information to potential adopters (Adesina & Zinnah, 1993). The strength of the innovation-diffusion-adoption paradigm is the recognition that adoption is a multistage process of collecting information, forming an attitude, taking the decision in adoption, implementing the new idea and then revising and reassessing decisions (Feder, Just, & Zilberman, 1982; Marsh, 1998; Everett M Rogers, 2002). However, this approach disregards the individual characteristics of the adopter (Posthumus et al., 2010).

The *adopter perception models* are grounded on the belief that farmers' characteristics and subjective perceptions of the new technology influence its adoption (I. Moumouni et al., 2013). The perception is determined by personal factors (e.g., personal values, education, and experience) as well as physical factors of the soil (e.g., nutrient content) and institutional factors (e.g., raising awareness through extension). However, this approach leaves out the social context that influences decision making.

The underlying theory of the *socio-psychological model*s is the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975) or Theory of Planned Behaviour (TPB) (Ajzen, 1991). From the perspective of TRA, behavioural intention is the most important predictor of behaviour. TRA links the behaviour of the individual to the attitude and social norms, which influence the intention to perform the behaviour. However, in some cases the performance of smallholders' behaviour in developing countries depends to some degree on non-motivational factors such as availability of opportunities and resources (e.g., time, money, skills). In case where a person has little control or power over his or her technology adoption behaviour (or believes he or she has little power) he or she might not engage in a behaviour despite a highly positive attitude and a high subjective norm towards the behaviour (e.g., lack of knowledge or opportunity). TPB considers this weakness and includes factors outside an individual's control that may affect intention and behaviour. A limitation of this approach is that other factors such as socio-demographics personality traits and economic constraints are not directly addressed.

2.3 Factors influencing agricultural technology adoption

The question of why agricultural technologies are not adopted as expected, regardless of their known benefits, has led to a substantial body of literature analysing farmers' adoption behaviour. These studies have attempted to identify factors that influence technology adoption in an agricultural context. Personal characteristics such as age, gender and education level are important determinants of agricultural technology adoption (Doss & Morris, 2001; Napier, Thraen, Gore, & Goe, 1984). Economic factors like income, farm size and household asset ownership have also proven to be essential for the technology adoption behaviour (Ervin & Ervin, 1982; Kabubo-Mariara, Linderhof, Kruseman, Atieno, & Mwabu, 2009; Marenya & Barrett, 2007; Nkonya et al., 2008). Furthermore, physical factors like slope, altitude, climate and soil quality (Kabubo-Mariara, 2012); and institutional factors such as credit, access to extension services, land tenure and the perception on the existence of the soil erosion problem can all affect the adoption decision of the farmer (Ervin & Ervin, 1982; Kabubo-Mariara, 2007, 2012; Meinzen-Dick, Raju, & Gulati, 2002; Migot-Adholla, Hazell, Blarel, & Place, 1991; Place & Swallow, 2000; E M Rogers, 1995; Shiferaw & Holden, 1998). Studies focusing on microeconomic incentives also consider profitability of the new technology as one of the most important determinants (Wossen et al., 2015). More recent studies have made first attempts to analyse the effect of social capital on agricultural technology adoption and discovered that the various forms of social capital significantly influence farmers' decisions. The forms of social capital and its role in smallholders' agricultural technology adoption are therefore discussed in more detail in the following subsection.

2.4 Social capital and its role in technology adoption

The concept of social capital arose in the field of social science (Bourdieu, 1986; Coleman, 2000; Putnam, 1993) and is increasingly recognised and used in economics (Becker, 1996) and development economics (Collier, 1998; Dasgupta, 1998). Due to its wide application, different definitions, classifications and measurement methods have been generated (see Bourdieu, 1986; Coleman, 2000; Putnam, 1993). Akcomak (2009) summarizes the various different definitions of social capital to four commonalities: (i) social capital results from social networks; (ii) the social network itself is not social capital but utilizing it leads to social capital; (iii) individuals invest in social relations with the expectation of return to the investment; and (iv) social capital may have negative and positive effects on outcome. Social capital is therefore commonly considered 'social' in that it involves social interactions and can be distinguished from human capital, which refers to the skills of individuals, e.g. education. As diverse as the definition of social capital is, so is its concept. To move towards a unified framework, Lollo (2012) developed a descriptive theory shown in Figure 1. According to Lollo (2012) four types of social capital – identifying, linking, bridging and bonding – can be identified along the three dimensions frequency, homogeneity and hierarchy. With the frequency of interaction between two individuals or between an individual and a group, the amount of social capital grows. Social capital can further be distinguished according to the degree of homogeneity between the parties. In reference to groups this could mean that the members share common values and interest. The last dimension of social capital is hierarchy, which quantifies the degree of concentration of contacts around a single individual and its social position within a group.

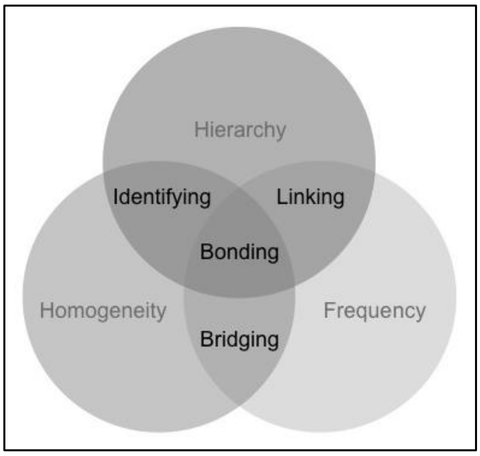

Figure 1: Social capital framework; source: own figure based on Lollo (2012)

As stated by Lollo (2012) these three dimensions define four forms of social capital: *Identifying* social capital is defined by the predominance of homogeneity and hierarchy. It describes social relationships formed in formal groups whose identity and function are linked to some common value or interest shared among participants (e.g., association of organic farmers).

Linking social capital is characterised by the combination of hierarchy and frequency. This refers to social relationships developed within or between formal organizations, that are by definition hierarchized, but whose ties are strengthened by frequency of interaction (Lollo, 2012). It describes the ability of individuals or groups to engage vertically with people in a different hierarchical position or other external agencies (Pretty, 2003). The relationship is characterised by well-defined roles, good coordination and interdependence among the actors. The absence of homogeneity implies that the nature of the group and its objectives is task oriented instead of value oriented (Lollo, 2012).

Bridging social capital is typified by frequency and homogeneity and describes relationships within informal groups such as a circle of friends or groups sharing similar interests. Expectations and obligations of the members evolve together with the repetition of contacts. Hierarchy is absent or not a dominant characteristic as people gather together mainly motivated by similarity. Due to these characteristics individuals trust one another and feel that they share some common value (Lollo, 2012).

The last social capital type, *bonding*, is the combination of all the three characteristics. Relationships characterized by high frequency, clear hierarchy and strong homogeneity are found within tight networks of close friends and relatives or horizontal relationships among equals within a localized community (Beugelsdijk & Smulders, 2003).

Social capital simply defined as relationships and networks built on trust, may be the most important assets that poor people possess as they are devoid of incomes, education, resources and financial assets (Njuki, Mapila, Zingore, & Delve, 2008). Studies have shown that rural communities characterized by strong social networks have better rates of technology diffusion and improved environmental management (Njuki et al., 2008).

Social capital may enhance the adoption of agricultural technologies in many ways: Firstly, social networks enable individuals to achieve goals which they are not able to achieve by themselves (Njuki et al., 2008). For example, adopters can take advantage of economies of scale when sharing transport to access inputs (Njuki et al., 2008), co-use machinery needed for the new sustainable practice, or to overcome their labour resource constraints with labour-sharing arrangements (Krishna, 2001). Members of a close community can rely on support and help when in need due to the extended number of friends or people they can trust (Njuki et al., 2008). Secondly, it further enhances adoption by providing access to informal credit that may relax a household's cash constraints. This feature of social capital may be of particular importance for poor farm households given that they may otherwise not be able to afford the cash outlays needed for investments in SLM practices (Wossen et al., 2015). Thirdly, strong network ties help farmers to cope with the risk associated with the adoption of new farming technologies by forming mutual insurance. Trust and good relationships enable households to jointly protect themselves against risks and shocks (Hunecke, Engler, Jara-Rojas, & Poortvliet, 2017). Lastly, social capital creates new forms of information exchange and eases the flow of information by reducing asymmetric information and transaction costs, thereby lowering information market inefficiencies (Abdulai, Monnin, & Gerber, 2008; E M Rogers, 1995). On the downside, social capital could potentially impede adoption by imposing a sharing obligation of benefits from SLM adoption (Di Falco & Bulte, 2011) or hinder adoption due to conflicts within the social network.

2.5 Gap in the literature and study contribution

While it has long been recognized as an important factor in rural sociological work (Katungi, Edmeades, & Smale, 2008) only relative recently have economic studies focused on examining the impact of social capital in the context of agricultural technology adoption and diffusion. The body of literature on the effect of social capital on agricultural technology adoption varies greatly with respect to the measurement of social capital and it is noticeable that scholars have not yet agreed on a uniform way of measuring social capital (e.g Grootaert, Narayan, Jones, & Woolcock, 2004; Narayan & Cassidy, 2001; Paxton, 1999).

The existing literature can broadly be divided into those classifying social capital according to the concept of structural and cognitive social capital (Msinde, 2018; Van Rijn, Bulte, & Adekunle, 2012), those distinguishing between bonding, bridging and linking social capital (Cramb, 2005; Njuki et al., 2008; Teshome, de Graaff, & Kessler, 2016), those putting a stronger emphasis on the aspects of trust and norms (Bouma, Bulte, & van Soest, 2008; Hunecke et al., 2017), those focusing on one type of social capital (Adong, 2014; Di Falco & Bulte, 2011; Munasib & Jordan, 2011; Wollni et al., 2010) or other studies looking at a broad variety of social capital variables (Bandiera & Rasul, 2006; Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009; Husen, Loos, & Siddig, 2017; Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2013; Nato, Shauri, & Kadere, 2016; Willy & Holm-Müller, 2013; Wossen et al., 2015; Wossen, Berger, Mequaninte, & Alamirew, 2013). However, this thesis is the first study applying Lollo's (2012) concept of identifying, linking, bridging and bonding social capital in the concept of agricultural technology adoption.

The existing literature on the effect of social capital on agricultural technology adoption also differs greatly regarding the technology under evaluation. Some papers focus on the effect of social capital on farmers' decision to adopt irrigation technology (Hunecke et al., 2017; Ramirez, 2013; Wossen et al., 2013), while others concentrate on improved resource management (Bouma et al., 2008; Katz, 2000), sustainable and improved agricultural practices (Bandiera & Rasul, 2006; Kassie et al., 2013; Munasib & Jordan, 2011; Nato et al., 2016), soil conservation practices (Husen et al., 2017; Njuki et al., 2008; Willy & Holm-Müller, 2013; Wollni et al., 2010) or land management (Lokonon & Mbaye, 2018; Teshome et al., 2016; Wossen et al., 2015). However, the combination of SLM practices analysed in this study are unique.

The relevant literature also differs regarding the geographical location of the studies. However only very few studies in this context have been carried out in Benin (Lokonon & Mbaye, 2018). As extensive literature reviews and meta-analyses (Knowler & Bradshaw, 2007; Wauters & Mathijs, 2014) have revealed almost none of the investigated factors affecting technology adoption in the agricultural sector apply universally and hence, it is important to take a case specific perspective.

In summary, this thesis differs from other papers examining the impact of social capital on agricultural technology adoption by (a) focusing on a new geographical location namely northern Benin, (b) taking into account the four forms – identifying, linking, bridging, bonding – of social capita and (c) considering a wide selection of SLM practices.

3 Methodology and data

The following section describes the methodological approach of this thesis by presenting the theoretical and conceptual framework, describing the survey and data and explaining the empirical model and procedure.

3.1 Theoretical model

Basic microeconomic models most often distinguish between consumers and producers. However, in most developing countries this separation is less clear for agricultural households where the deciding entity is both a producer and consumer. Becker's (1965) unitary household model builds the foundation for the agricultural household model and the analytical framework used in most of the early empirical efforts to investigate the behaviour of agricultural households (Singh, Squire, & Strauss, 1986). Agricultural households in the role of a producer choose the allocation of labour and other inputs to production, while as a consumer they choose the allocation of income from farm profits and labour sales to the consumption of commodities and services. Farm profits are gained through explicit and implicit profits from goods produced and consumed by the same household, and consumption consists of both purchased and self-produced goods (Taylor & Adelman, 2003).

For the purpose of studying technology adoption, the farm household model has been expanded to include the technology adoption decision (e.g., (Fernandez-Cornejo, Hendricks, & Mishra, 2005). Following Fernandez-Cornejo et al. (2007) and Willy & Holm-Müller (2013), the theoretical model is therefore a modification of the agricultural household model (Singh et al., 1986) to accommodate technology adoption decisions. The agricultural household model describes the farm household's optimization behaviour as maximizing utility U defined by the objective function:

$$Max\ U = U(G, L, \boldsymbol{H}, \varphi) \tag{1}$$

where G = purchased consumption goods, L = leisure, $\boldsymbol{H}$ = vector of other factors exogenous to current smallholder decisions, and φ = other household characteristics. Household utility is maximized subject to three constraints:

$$\text{Income constraint: } P_g\, G = P_q Q - \boldsymbol{W}_x \boldsymbol{X}' + WM + I \tag{2}$$

$$\text{Time constraint: } T = F(\tau) + M + L,\ M \geq 0 \tag{3}$$

$$\text{Production constraint: } Q = Q[X(\tau), F(\tau), \boldsymbol{H}, \tau, \boldsymbol{R}],\ \tau \geq 0 \tag{4}$$

where P_g and G represent the price and quantity of the goods purchased for consumption; P_q and Q denote the price and quantity of the farm output; $\boldsymbol{W}_x$ and $\boldsymbol{X}$ are row vectors of price and quantity of farm inputs; farm inputs are a function of the intensity of technology adoption τ; W represents off-farm wages paid for the amount of time working off-farm M; I is exogenous income such as government transfers; T denotes the total time endowment of the household, which is split between leisure L, off-farm work M and on farm activities F, which is a function of the intensity of technology adoption τ since some SLM measures are labour intensive while other practices free time to allocate to other activities, such as social networking or participation in farmers associations; **R** is a vector of exogenous factors shifting the production function. The household's income and production constraints can be combined by substituting Equation 4 into 2:

$$P_g\, G = P_q Q[\boldsymbol{X}(\tau), F(\tau), \boldsymbol{H}, \tau, \boldsymbol{R}] - \boldsymbol{W_x X}(\tau)' + WM + I\ . \tag{5}$$

The first order optimality conditions (Kuhn–Tucker conditions) are obtained by setting up a Lagrangian function:

$$\begin{aligned}\mathcal{L} = {} & U(G, L, H, \varphi) \\ & +\lambda\{P_q Q[X(\tau), F(\tau), \boldsymbol{H}, \tau, \boldsymbol{R}] - \boldsymbol{W_x X}(\tau)' + WM + I - P_g\, G\} \\ & +\mu[T - F(\tau) - M - L]\end{aligned} \tag{6}$$

and maximising $\mathcal{L}$ over F, τ, G and L and minimising the function over the Lagrange multipliers λ and μ. The technology adoption decision condition can be obtained from the following Kuhn-Tucker conditions:

$$\frac{\partial\mathcal{L}}{\partial F} = \lambda P_q \frac{\partial Q}{\partial F} - \mu = 0 \tag{7}$$

$$\frac{\partial\mathcal{L}}{\partial \tau} = \lambda\left[P_q\left(\frac{\partial Q}{\partial X}\frac{d\boldsymbol{X}'}{d\tau} + \frac{\partial Q}{\partial F}\frac{dF}{d\tau} + \frac{\partial Q}{d\tau}\right) - W_x\frac{d\boldsymbol{X}'}{d\tau}\right] - \mu\frac{dF}{d\tau} \le 0, \tag{8}$$

$$\tau \ge 0, \qquad \tau \cong \frac{\partial\mathcal{L}}{\partial \tau} = 0$$

$$\frac{\partial\mathcal{L}}{\partial G} = U_G - P_g\lambda = 0 \tag{9}$$

$$\frac{\partial\mathcal{L}}{\partial L} = U_L - \mu = 0 \tag{10}$$

$$\frac{\partial\mathcal{L}}{\partial \lambda} = P_q Q[\boldsymbol{X}(\tau), F(\tau), \boldsymbol{H}, \tau, \boldsymbol{R}] - \boldsymbol{W_x X}(\tau)' + WM + I - P_g\, G = 0 \tag{11}$$

$$\frac{\partial\mathcal{L}}{\partial \mu} = T - F(\tau) - M - L = 0 \tag{12}$$

where U_G, U_L are the partial derivatives of the function U with respect to G and L respectively. Noting that the expression in the round brackets in (8) is the total derivative $\frac{dQ}{d\tau}$ and dividing (8) by λ we obtain:

$$P_q\frac{dQ}{d\tau} - \boldsymbol{W}_x\frac{d\boldsymbol{X}'}{d\tau} - \frac{\mu}{\lambda}\frac{dF}{d\tau} \le 0 \tag{13}$$

From (9) and (10) we can see that $\frac{\mu}{\lambda} = P_g\frac{U_L}{U_G}$ so then

$$P_q \frac{dQ}{d\tau} - \boldsymbol{W}_x \frac{d\boldsymbol{X}'}{d\tau} - P_g \frac{U_L}{U_G} \frac{dF}{d\tau} \leq 0 \quad (14)$$

which is the technology adoption decision condition. $P_q \frac{dQ}{d\tau}$ can be interpreted as the marginal benefits of adoption while the marginal cost of adoption consists of the marginal cost of production inputs $\boldsymbol{W}_x \frac{d\boldsymbol{X}'}{d\tau}$ and the marginal cost of farm work $P_g \frac{U_L}{U_G} \frac{dF}{d\tau}$ brought up by the technology adoption, valued at the marginal rate of substitution between leisure and consumption of goods. Hence, the condition states that the optimal extent of technology adoption occurs when the value of marginal benefits of adoption is equal to the marginal cost of adoption (Willy & Holm-Müller, 2013). Assuming that the household makes rational decisions, this means that the technology will be adopted if the marginal benefit is greater than or equal to the marginal cost.

Social capital is not directly considered in the model by Fernandez-Cornejo et al. (2007). It is assumed that social capital accumulates mutually during other business and non-business activities. Hence, the time assigned to network building and maintaining is not considered to be a variable on its own but is rather part of all the labour variables noted in the time constraint. The same holds in the case for the production constraint where human capital may as well be a function of social capital since it influences the knowledge of a household on SLM technologies. Social capital is assumed to influence the adoption decision in several ways: Firstly, social capital improves information flows (Robalino, 2000) and hence, reduces the information cost and risk due to the information shortage associated with the new technologies. The type of existing social networks determines the quality of information and the frequency of interaction defines the density of information flow. Secondly, social capital facilitates coordination and cooperation among social network members (Robalino, 2000). Depending on the form of social capital it can lead to sharing arrangements of labour, technical facilities and risk between farmers. Such social mechanisms reduce input and labour costs and provide informal insurance in cases of low yields.

Regarding the model above and given the cross-sectional character of the data, Fernandez-Cornejo et al. (2007) proposes to use the implicit function theorem to derive an expression for the technology adoption as a function of wages, prices, human capital, non-labour income and other exogenous factors. In the reduced form representation of technology adoption these factors can be replaced by observable farm and household characteristics. The following section explains, in consideration of the literature, the underlying causal relationships between the factors and identifies relevant variables that will be used in the empirical models to analyse household SLM adoption and extent of use.

3.2 Conceptual framework

Given the comprehensive theoretical frameworks in section 2.2, the aim of this study is to combine an economic model of technology adoption with aspects of the other three theories to form an interdisciplinary framework. The reason for choosing this approach is that pure economic adoption models solely based on utility and profit maximisation fail to include social variables which are likely to co-determine a household's adoption decision. They do not consider social processes and structures that influence household's resource allocation. Likewise, theories in sociological studies downplay economic factors (Mbaga-Semgalawe & Folmer, 2000). Hence in this thesis the adoption and level of SLM adoption is conceptualized as a decision-making model including a two-stage decision process which is influenced by five variable components.

Figure 2 shows the sociological-economic model of adaptation and the relationships between the dependent and explanatory variables. The underlying rationale of the sequential process is that for a household to reach each of the two stages it goes through a mental decision process. The stages of the household's decision process include (1) the SLM adoption decision i.e. whether or not a household applies SLM practices and (2) the extent of adoption or efforts devoted to SLM. It is assumed that the first decision step is preceded by an information acquisition period, also called an awareness or learning period (Adegbola & Gardebroek, 2007; Atanu, Love, & Schwart, 1994). The factors influencing the two decision steps can be compiled as five components: perception of the land quality or physical properties, personal characteristics, economic factors, institutional determinates and social capital.

Physical characteristics, such as slope, altitude, climate and soil quality have been considered in previous studies as critical factors influencing the adoption of agricultural technologies (Kabubo-Mariara, 2012). Plot characteristics are assumed in this conceptual framework to affect both steps of the decision-making process because they partly determine the degradation degree and potential, and hence whether it is necessary to apply SLM technologies and to what extent they are required. Since data on household's plot characteristics is lacking, the perception of the land quality will be used instead. A similar argument as for the actual plot properties applies for the perceived quality of the land. It is assumed that the recognition of the degradation problem will influence the decision to adopt SLM and depending on the degree of perceived degradation a varying number of SLM measures will be applied.

The second component can be described as personal characteristics and attributes of the farmer including age, education, gender, risk aversion, etc. These attributes may determine a farmer's willingness to inform himself or herself about SLM practices as well as his or her capability to implement the SLM practices on their land.

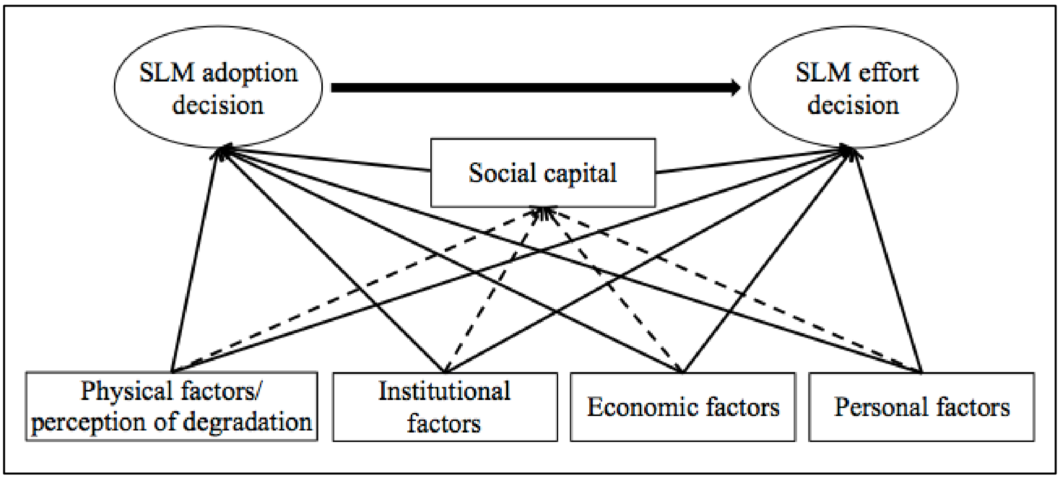

Figure 2: The socio-economic decision model; source: own figure

Another component is the economic profile of the farm enterprise such as farm size, number of farm animals, location and profit. The given farm conditions may serve to facilitate the adoption of SLM or may produce constraints to actual implementation.

A farmers' decision to adopt and the extent of adoption may also be influenced by public institutions which may provide extension service and other facilities that intervene to alter a farmer's disposition towards land degradation control and/or to offset economic or technical management constraints to practice SLM. The institutional factors considered are for example access to credit or extension services, participation in development programmes or land tenure.

The last component consists of social capital variables such as participation in village groups or farmers' associations, kinship or business networks. Social capital can facilitate the exchange of information and knowledge on SLM and lowers transaction costs associated with the adoption as well as reducing the risk associated with the new technology. From the literature it is unclear whether social capital is an exogenous factor determining a farmer's decision or whether it is influenced by personal or other characteristics. Tenzin, Otsuka & Natsuda (2013) found that group membership is endogenous, while Munasib & Jordan (2011) found it to be exogenous in most cases, and again others could not find appropriate instrument variables for their social capital variables to test for endogeneity (Bouma et al., 2008).

3.3 Data

As part of the collaborative adoption research by the Institute for Advance Sustainability Studies (IASS) a household survey was conducted between July and August 2016 in two of ProSOL's intervention villages in northern Benin. Figure 3 shows the location of Kabanou in the commune of Bembèrèkè and Sinawongourou consisting of Sinwongourou Bariba and Sinwongourou Peul in the commune of Kandi. The sample of 100 households per village was drawn using a stratified random sampling method. This corresponds to about 30 % and 9 % of the village population respectively. The data was collected through personal interviews based on structured questionnaires with the household head or a household member who felt qualified to answer questions about the household. They were asked information about their living standards, agricultural production, input use, SLM practices implemented, perceived soil quality, membership within village groups, involvement in conflicts and land disputes, access to external services and markets, as well as household socio-economic and demographic characteristics. The questionnaire is presented in the Appendix 1. After the interviewers were trained, a pre-test survey was conducted at a different site.

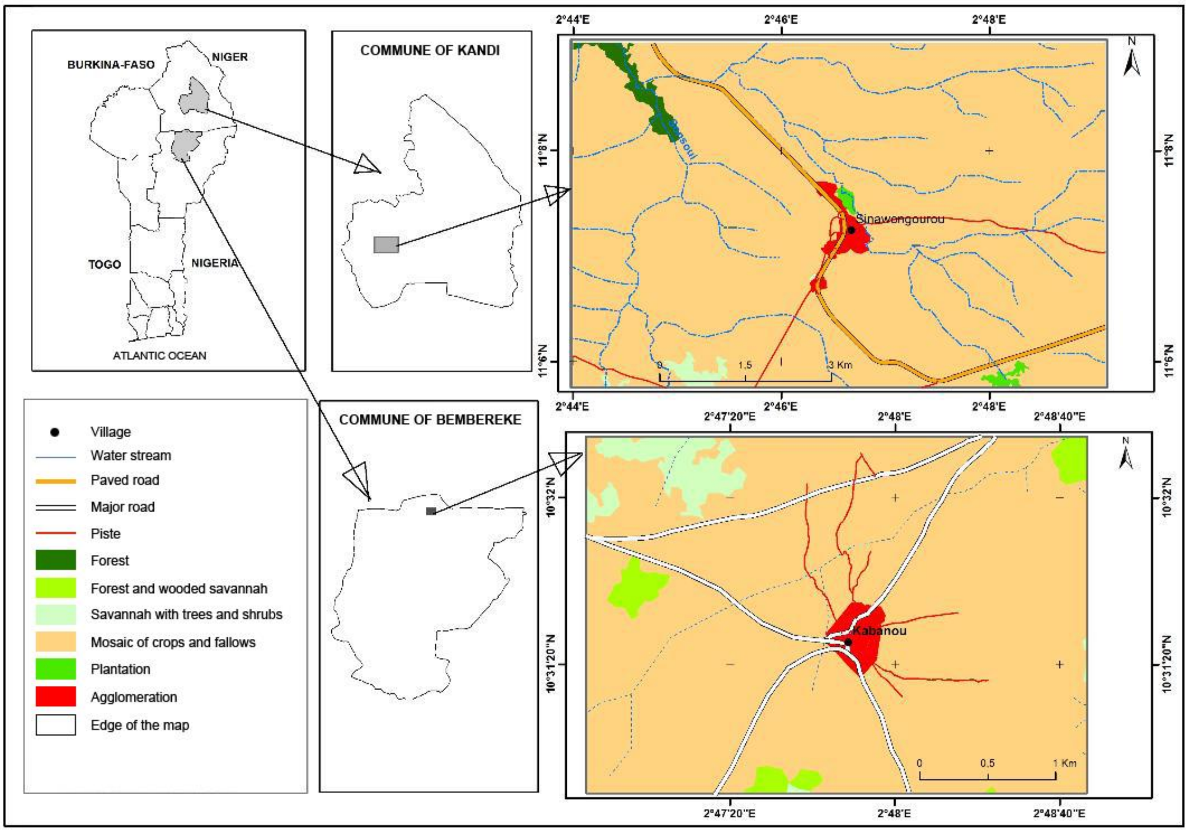

Figure 3: Map of the two study villages Sinawongourou and Kabanou in northern Benin; source: own figure

Except for one household, all other household in the survey apply at least one of the 14 SLM practices considered in this study. The maximum number of SLM technologies a household of this survey adopted is nine. On average the households from Kabanou apply a little more than four SLM practices and in Sinawongourou just under four technologies. The most common SLM practices are the application of mineral fertiliser (192 adopters), crop rotation (143 adopters), agroforestry (143 adopters), burying crop residues (101 adopters) and use of manure (85 adopters). Little attention is paid to the two legume cover crop species aeschynomene histrix (1 adopter) and stylosanthes guianensis (2 adopters) and the method of applying compost (4 adopters) and growing fodder crops (9 adopters). Also, less popular is to leave parts of the land fallow (16 adopters) or to grow mucuna pruriens (15 adopters) or pigeon pea (21 adopters). It is more common to apply anti-erosion measures (25 adopters) or to intercrop cereals and legumes (33 adopters). In total, 43 of the 200 households have participated in the ProSOL project. About 90 % of the households in the sample use one or two distribution channels to sell their agricultural products, while about 4 % do not sell their product at all and 6 % make use of three sales channels. In both villages, around 60 % of the respondents are a member of at least one village group of which 8 % belong to more than one group. 19 % of the respondents state that their household has experienced land disputes but 72 % of them were able to resolve the issue. More than a third of the households have been involved in conflicts with other crop or animal farmers in the past. About 87 % of the respondents are married with the other 13 % either being single, divorced or widowed. On average the respondents have 6 family members (children and spouses) with the standard deviation of 3.63 indicating large differences between households. This is mainly due to the number of children that vary from 0 to 16 in the sample. Table 1 and Appendix 2 include further information on the sample characteristics and the variables used for the empirical analysis. The reduced form of the database can be accessed here.

Since the data had already been collected at the time of the idea generation for the thesis topic, the analysis is limited to the predefined data scope and given collected variables (secondary statistical analysis). Due to the nature of the data (cross-section, non-experimental) potential endogeneity concerns emerge (reverse causality, omitted variables), which is addressed and tested in the analysis.

3.4 Empirical analysis

The following section outlines the empirical framework by presenting the empirical models used to analyse households' adoption and extent of adoption of SLM. It describes the models' variables and the empirical strategy. All estimations were computed using Stata 13 and the code can be accessed here.

3.4.1 Empirical framework

The empirical estimation is based on the available data and attempts to capture the two-stage decision process of a household regarding the implementation and use of SLM. The first stage is carried out using the adoption model whereas the second stage is represented by the effort model.

Adoption model

For the adoption model it is assumed that a particular farm household considers implementing a new SLM practice if the expected net benefit from adoption is higher compared to non-adoption. The adoption model analyses the effects of social capital and other observable characteristics on the adoption of a SLM component C_h. It is estimated using ordinary least squares (OLS) method:

$$\begin{aligned} C_h = {} & \beta_0 + \beta_1 \text{ProSOLParticipation}_h + \beta_2 \text{SalesChannels}_h + \beta_3 \text{GroupMemberships}_h \\ & + \beta_4 \text{FamilyMembers}_h + \beta_5 \text{Conflict}_h + \beta_6 \text{LandDispute}_h + \beta_7 \text{LandQuality}_h \\ & + \beta_8 \text{Commune}_h + \beta_9 \text{FarmSize}_h + \beta_{10} \text{LivestockOwnership}_h \\ & + \beta_{11} \text{Ethnicity}_h + \beta_{12} \text{Gender}_h + \beta_{13} \text{LandTenure}_h + \beta_{14} \text{Participation}_h \\ & + \beta_{15} \text{Warrantage}_h + \beta_{16} \text{Credit}_h + \beta_{17} \text{Support}_h + \varepsilon_h \end{aligned} \tag{15}$$

with h number of households and where β_0 is a constant, β_{1-17} are parameters to be estimated and ε_h captures a household specific error term. In total 14 SLM technologies that are appropriated for the onsite conditions in northern Benin are considered for the dependent variables of the adoption model. These practices are described in section 2.1.

Effort model

An ordinal probit model is applied to analyse how the extent of a household's SLM application is influenced by social capital and other observable factors. One might wonder why the information on the number of adopted SLM practises is not treated as a count variable (instead of an ordinal categorical nature) implying the use of a Poisson regression model. However, the Poisson regression has the underlying assumption that all events have the same probability of occurrence (Wollni et al., 2010). But in the case of technology adoption, the probability of adopting the first SLM practice could differ from the probability of adopting several practices, given that in the latter case the household has already gained some experience with SLM and has been exposed to information about SLM in general (Teklewold, Kassie, & Shiferaw, 2013). The ordered probit model specification is:

$$Y_h^* = \gamma_0 + \boldsymbol{\gamma_1} \boldsymbol{X}'_h + \boldsymbol{\gamma_2} \boldsymbol{S}'_h + \mu_h \tag{16}$$

where Y_h^* is the underlying latent variable that indexes the extent to which a household h is engaged in SLM and $\boldsymbol{X}'_h$ is a vector of control variables including institutional, economic and personal characteristics, as well as the variable for a household's perception of the land degradation problem. The vector $\boldsymbol{S}'_h$ includes social capital variables, γ_0 represents a constant, $\boldsymbol{\gamma_1}$ and $\boldsymbol{\gamma_2}$ are vectors of parameters to be estimated and μ_h captures a household specific error term. The estimation of the latent variable Y_h^* is based on the observable ordinal discrete choice of the household Y_h. It takes the value Y_h = 1 if a household adopted one SLM practice, Y_h = 2 if two practices were implemented and so on until Y_h = 9 if a household had implemented nine SLM technologies, which was the highest adoption level in the sample:

$$Y_h = \begin{cases} 1 \text{ if } Y_h^* \leq \theta_1 \\ 2 \text{ if } \theta_1 < Y_h^* \leq \theta_2 \\ 3 \text{ if } \theta_2 < Y_h^* \leq \theta_3 \\ 4 \text{ if } \theta_3 < Y_h^* \leq \theta_4 \\ 5 \text{ if } \theta_4 < Y_h^* \leq \theta_5 \\ 7 \text{ if } \theta_5 < Y_h^* \leq \theta_6 \\ 7 \text{ if } \theta_6 < Y_h^* \leq \theta_7 \\ 8 \text{ if } \theta_7 < Y_h^* \leq \theta_8 \\ 9 \text{ if } \theta_8 \leq Y_h^* \end{cases} \tag{17}$$

where Y_h is the number of SLM practices implemented by a household and θ are threshold parameters to be estimated. The parameters in the effort model were estimated using maximum likelihood.

3.4.2 Description of variables

Table 1 presents the variables used in the estimations and shows their description, descriptive statistics and expected signs. The following section describes the social capital variables used in this study in more detail. The detailed description of the other explanatory variables can be found in Appendix 3. A household's social capital is captured using six variables. The challenge of measuring social capital is that unlike other forms of capital it is not directly observable (Akcomak, 2009).

The first variable is *participation in ProSOL's extension programme (identifying social capital)*. This dummy variable indicates whether a household participates in the extension programme by ProSOL or not. Meetings and activities in groups allow farmers to exchange knowledge and learn from one another. At the same time, it gives them the chance to expand their business network beyond the farmer's level and exchange information with experts on SLM technologies and receive support for implementation when needed. Therefore, it is hypothesized that the participation in the extension programme by ProSOL positively influences the SLM adoption and extent of SLM implementation among smallholder farmers.

The second variable tries to capture a household's market network (linking social capital). The *number of sales channels* a household uses to distribute its agricultural products proxies the degree of market integration and may also capture contracts between farmer and buyer that are common in the presence of imperfect markets (Kassie et al., 2013). It is believed that a variety of different distribution channels offers a more stable market-outlet services and a diverse information source to farmers, which create more reliable conditions for credit and input access. Therefore, it is expected that a household's market network size has a positive effect on the probability of adoption and the number of applied SLM practices.

The *number of group memberships* in village groups captures the extent of bridging social capital and represents whether household members have memberships in village groups such as women's institutes or farmer's associations. Smallholders who do not have contacts with extension agents may still find out about new technologies from their group networks, as they share information and learn from each other. The network among the members of these groups may enable farmers to access inputs on schedule and overcome credit constraints (Adong, 2014). It is assumed that the more village groups a farmer joins the larger is his or her potential network and there is a higher chance that he or she receives support from other members. Therefore, it is hypothesised that with an increasing number of group memberships the probability of SLM adoption and extent of use is rising.

The next variable captures social capital in the form of family network (bonding social capital). In many developing countries, extended and close family members serve as a social safety net and informal insurance system (Fafchamps & Gubert, 2007; Fafchamps & Lund, 2003). Hence, they have a better chance to adopt new technologies because they are able to experiment with new farming practices without excessive exposure to risk They also provide each other with relevant information for example regarding business purposes. Individuals with a family are therefore more likely to hear about SLM technologies because they benefit from a larger information network. However, having to look after not just oneself but having the responsibility for others may lead to more risk averse behaviour, inhibiting the implementation of new farming practices. Furthermore, compulsory sharing among family members may invite free riding behaviour reducing incentives for hard work and may therefore lead to a social dilemma within the kin network (Di Falco & Bulte, 2013, 2015). The expected sign of the coefficient measuring the *number of close family members* (spouses and children) a respondent has is therefore indeterminate.

Besides the size of a household's network also the quality of the social ties is expected to be relevant for the technology adoption decision. On the one hand, good relationships between individuals lead to trust and dependency and allow the parties to rely on each other more. On the other hand, the more the relationship is characterized by past conflicts and disharmony the likelier it is that this social interaction will be of no (future) use. Hence, whether a household has been involved in a *conflict* with crop or animal farmers or whether they have been part of *land disputes* is used to measure the quality of a household's social capital. The involvement in both types of conflicts are hypothesized to impede the adoption and use of SLM practices.

Table 1: Description of dependent and explanatory variables

Variable	Description (measurement)	Mean	SD	Expected sign
Dependent variables				
Adoption	Current use of SLM technology			
Mineral fertiliser	Current use of “mineral fertiliser” (1=yes)	0.96		
Fallow	Current use of “fallow” (1=yes)	0.08		
Crop rotation	Current use of “crop rotation” (1=yes)	0.72		
Cereal/legume	Current use of “cereal/legume association” (1=yes)	0.17		
Residues	Current use of “burying crop residues” (1=yes)	0.51		
Pigeon pea	Current use of “pigeon pea” (1=yes)	0.12		
Mucuna	Current use of “mucuna pruriens” (1=yes)	0.08		
Stylosanthes	Current use of “stylosanthes guianensis” (1=yes)	0.01		
Aeschynomene	Current use of “aeschynomene histrix” (1=yes)	0.01		
Compost	Current use of “compost” (1=yes)	0.02		
Excrements	Current use of “animal excrements” (1=yes)	0.43		
Fodder	Current use of “fodder crops” (1=yes)	0.05		
Agroforestry	Current use of “agroforestry” (1=yes)	0.72		
Anti-erosion	Current use of “anti-erosion measures” (1=yes)	0.13		
Effort	Number of adopted SLM technologies (ordered numbers: 0,1,2, …, 14)	4.16	1.73	
Explanatory variables				
Perception variable				
Land quality	Perception of land quality of the household’s land (1=fertile till 5=very eroded)	2.12	0.97	+
Social capital variables				
Quantity	Social capital size			
Identifying	Participation in ProSOL extension programme (1=yes)	0.22		+
Linking	Market network (Number of sales channels)	1.53	0.66	+
Bridging	Membership in village group (Number of group memberships)	0.65	0.59	+
Bonding	Family network (Number of close family members)	6.21	3.63	+/–
Quality	Social capital quality			
Conflict	Involved in a conflict with crop/animal farmer (1=yes)	0.38		–
Land dispute	Involved in disputes over land (1=yes)	0.19		–
Economic factors				
Commune	Commune in which farm is located (1=Bembèrèkè)	0.5		–
Farm size	Farm size (in ha)	7.94	5.90	+/–
Livestock ownership	Number of farm animals owned	27.36	27.31	+/–
Personal factors				
Ethnicity	Ethnicity (1=Bariba, 2=Peul, 3=Gando, 4=other)	1.83		+/–
Gender	Gender (1=male)	0.82		+/–
Institutional factors				
Land tenure	Land ownership (1=yes)	0.81		+
Participation	Participation in development project (1=yes)	0.27		+
Warrantage	Member of inventory credit system (1=yes)	0.04		+
Credit	Access to agricultural credit in the last 5 years? (1=yes)	0.40		+
Support	Receive agricultural advice for food production? (1=yes)	0.16		+
Instrumental variables				
Cotton	Household grows cotton (yes=1)	0.71		
Village	Village in which farm is located (1=Kabanou, 2=Sinawongourou Peul, 3=Sinawongourou Bariba)	1.78		
Heard ProSOL	Heard of ProSOL programme (yes=1)	0.53		
Motorcycle	Number of motorcycles owned by household	0.89	0.89	

Source: own calculations

3.4.3 Empirical strategy

Adoption model

Since the variation of adoption and non-adoption of some of the SLM technologies is very small, meaning that either a lot or almost none of the households in the survey adopted a specific SLM practice, it was not possible to apply probit regression for each individual SLM technology. Instead exploratory principal component analysis (PCA) was used to categorise and reduce the SLM practices into combined components. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy test was undertaken to measure the degree to which the variables are related and thereby assess the appropriateness of using factor analysis on the data. In addition, Bartlett's test of sphericity was applied to examine whether the correlations between the variables were large enough for PCA. The final indices were used as dependent variables in the adoption model.

However, the decision to adopt the different SLM practices may not be fully independent from one another and so the error terms of their equations may be correlated. Their independence was therefore tested by regressing the components obtained from PCA on the control variables and social capital variables as a system of linear equations using seemingly unrelated regression estimation (SURE). The Breusch Pagan test was used to test the assumption that the errors across equations are correlated.

From the literature on technology adoption and the conceptual framework it is not clear whether the different forms of social capital can be treated as exogenous. Since a household's social capital might be influenced by household and external characteristics, the direct estimation of the effect of social capital on SLM adoption could be subject to endogeneity bias. Endogeneity bias arises if un-observed household characteristics are correlated with the error term. In the case of membership in village groups and participation in ProSOL's extension programme, it is possible that farmers self-select into the group or programme, so that their unobserved characteristics will systematically differ from non-members or non-participants. Similarly, it is likely that individual and household characteristics simultaneously determine a household's land management behaviour as well as the size of the immediate family and the scope of the market network. For example, Wossen et al. (2015) remark that wealthier households might have more opportunities to possess social capital compared to poorer households. That is, poorer households are more likely to practice subsistence farming and hence do not sell their products leading to very little or no social capital in the form of market networks (linking social capital). At the same time wealthier households might be able to care for more children and spouses. However, the wealth of a household is expected to influence technology adoption, too. Hence, participation in ProSOL's extension programme, membership in village groups, market network size and family size as well as the choice to adopt SLM techniques might simultaneously be determined based on specific farm household characteristics. This could lead to a reverse causation between the four forms of social capital and the household's decision to adopt SLM practices. To test whether omitted variable bias, simultaneous causality and endogeneity problems are caused by the social capital variables an instrumental variable regression approach and Durbin and Wu-Hausman tests are carried out. A valid instrument must satisfy two conditions, known as the instrument relevance condition corr $(Z_h, S_h) \neq 0$, that is the instruments Z_h are correlated with the endogenous variables S_h and the instrument exogeneity condition corr $(Z_h, \varepsilon_h) = 0$ which says that the instruments are uncorrelated with the error in Equation 15. To checked for weak instruments the first-stage *F*-statistic was computed testing the hypothesis that the coefficients on the instruments equal zero in the first stage regression of two-stage least square (2SLS). However, it is not possible to test the hypothesis that the instruments are exogenous (Stock & Watson, 2014).

In order to find appropriate instruments for the social capital variables, community and cultural characteristics in the two study villages are explored. Whether a household has heard of the ProSOL programme (*heard ProSOL*) acts as an instrumental variable for the participation in the ProSOL programme. Individuals who do not know of the programme are very unlikely to participate. Whilst the knowledge of the programme is directly correlated with the participation, it is very unlikely that it is correlated with the adoption of new SLM techniques. The number of distribution channels of a household is likely to be influence by the distance and ease of access to markets. Hence, a categorical variable indicating the location of a household by *village* was used as an approximation for the distance to markets and as an instrumental variable for the market network of a household. Since the village Kabanou has a disadvantage regarding road infrastructure and access to markets, farmer's living in Kabanou are less likely to have social capital from market networks compared to households living in Sinwongourou Bariba and Sinwongourou Peul. The village Kabanou acts as the reference category. A dummy variable of whether a household produces *cotton* serves as an instrumental variable for the number of memberships in village groups for a particular household. Since a lot of the village groups are built around the theme of cotton production, a household growing cotton is more likely to join a number of village groups than a household that does not. Therefore, cotton farmers are more likely to have social capital from group memberships than non-cotton farmers. However, the production of cotton is unlikely to affect the adoption of SLM practices, since most of the households grow a variety of different crops. A possible instrumental variable for the number of close family members is the ownership of machinery or means of transport. For example, a motorcycle is seen as a status symbol in Benin and is an indicator for wealth. Hence the number of owned motorcycles may increase the chance of marriage (number of spouses) and may allow for a higher number of children due to higher wealth (number of children). While the instrumental variable *motorcycle* directly affects the number of close family members in a household, it is unlikely that it is correlated with the adoption of new SLM techniques.

A 2SLS strategy is followed in which the four social capital variables – identifying, linking, bridging and bonding – are instrumented with the variables *heard ProSOL, village, cotton and motorcycle*. The first stage regression of 2SLS relates each social capital variable S_h to the exogenous variables $\boldsymbol{X}_h'$ and the instrument variables $\boldsymbol{Z}_h'$:

$$S_h = \alpha_0 + \alpha_1 \boldsymbol{X}_h' + \alpha_2 \boldsymbol{Z}_h' + v_h \tag{18}$$

where $\alpha_0,\ \alpha_1$ and α_2 are unknown regression coefficients and v_h is an error term. The predicted values from the first regression enter the second stage, where the SLM components C_h are regressed on the predicted values of social capital $\widehat{\boldsymbol{S}}_h'$ and exogenous variables $\mathbf{X}_h'$:

$$C_h = \beta_0 + \beta_1 \boldsymbol{X}_h' + \beta_2 \widehat{\boldsymbol{S}}_h' + \varepsilon_h \tag{19}$$

where β_0 is an intercept, $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$ are vectors of parameters to be estimated and ε_h is the error term of the adoption model.

Effort model

The dependent variable of the effort model, stands for the intensity of SLM application. A suitable indicator of adoption intensity would be the proportion of area under application, however, the survey did not measure such a variable. Therefore, the number of installed SLM technologies is used instead to measures the extent to which a household applies SLM. This has the advantage that not only the range of applied practices but also the possibility of synergies between practices is captured. However, it is not clear if all SLM technologies are appropriate for every household's land since data on households' plot characteristics are lacking.

To avoid selection bias in the model, one observation (the one household that did not adopt any SLM practices) was dropped. In order to interpret the effect of a regressor in a meaningful way marginal effects on each ordered response were computed. The control function approach was used to empirically test whether the social capital variables are endogenous. First, each social capital variable is regressed on all the exogenous variables and the instruments (see Equation 18). The residuals are calculated and are then included in the ordered probit estimation to correct for endogeneity. This technique of inserting first stage residuals in the main model is in the spirit of the Wu–Hausman procedure (Wooldridge, 2010). The ordered probit model corrected for endogeneity is then specified as follows:

$$Y_h^* = \gamma_0 + \gamma_1 \boldsymbol{X}_h' + \gamma_2 \boldsymbol{S}_h' + \gamma_3 \widehat{\boldsymbol{v}}_h' + \mu_h \tag{20}$$

where $\widehat{\boldsymbol{v}}_h'$ is a vector of residuals from Equation 18. The usual t-test for the hypothesis of significance is employed: H_0: $\gamma_3 = 0$ (exogenous), H_1: $\gamma_3 \neq 0$ (endogenous).

4 Results

Section 4.1 presents the results of the exploratory PCA that was used to compile the 14 SLM practices into components. Section 4.2 and 4.3 show the results of the adoption models and effort model which were used to analyse the effect of social capital and other control variables on the adoption and extent of adoption of SLM respectively.

4.1 Principal component analysis

The SLM practices were subject to explorative factor analysis using PCA. The KMO value was above the critical value of 0.5 (KMO = 0.563) and the chi-square statistic from Bartlett's test of sphericity was 202.006 and statistically significant ($p < 0.000$). Thus, the null hypothesis that the variables are not inter-correlated was rejected, indicating that PCA was appropriate. From the eigenvalues presented in Table 2, one can determined the number of principal components (PCs) to be extracted. Since a useful component must account for more than one unit of variance or have an eigenvalue greater than one, the results supported a solution with six PCs. However, from Table 3 it can be seen that the sixth component only contains one SLM practice and does not account for a much larger proportion of the variance than the original variable. Therefore, five PCs are used instead of six which together explain 51.5 % of total variance. A Varimax orthogonal rotation of PC loadings was performed to determine the number of items included in each PC (Table 3). Only variables with factor loadings greater than 0.3 were used for the factor analysis. The higher the absolute value of the loading, the more the variable contributes to the component.

Table 2: Eigenvalues of exploratory principal component analysis

Principal component	Eigenvalue	Difference	Percent of variance explained
1	1.932	0.389	13.8
2	1.543	0.099	11.0
3	1.444	0.282	10.3
4	1.161	0.031	8.3
5	1.130	0.083	8.1
6	1.048	0.112	7.5
7	0.936	0.062	6.7
8	0.858	0.015	6.2
9	0.858	0.136	6.1
10	0.723	0.059	5.2
11	0.664	0.017	4.7
12	0.647	0.108	4.6
13	0.540	0.039	3.8
14	0.501		3.6

Source: own calculations

Table 3: Principal component (PC) loadings for exploratory component analysis with a Varimax orthogonal rotation

Variable	PC1	PC2	PC3	PC4	PC5	PC6	Unexplained
Mineral fertiliser	- 0.033	0.139	0.086	**- 0.492**	0.270	0.079	0.528
Fallow	- 0.089	- 0.079	- 0.090	- 0.045	**0.674**	- 0.061	0.418
Crop rotation	0.227	0.051	0.037	0.070	**0.418**	0.154	0.584
Cereal/legume	0.075	- 0.048	**0.615**	- 0.038	0.160	0.117	0.366
Residues	**0.496**	0.099	- 0.189	0.231	- 0.162	0.161	0.382
Pigeon pea	0.259	**0.523**	- 0.022	- 0.011	0.068	- 0.159	0.384
Mucuna	0.295	- 0.063	- 0.192	- 0.074	0.235	- 0.202	0.680
Stylosanthes	- 0.007	- 0.020	- 0.011	- 0.025	- 0.011	**0.905**	0.119
Aeschynomene	- 0.190	**0.679**	- 0.031	- 0.133	- 0.145	- 0.013	0.334
Compost	- 0.004	- 0.049	- 0.012	**0.656**	0.015	- 0.032	0.400
Excrements	**- 0.310**	0.030	0.175	**0.375**	0.285	- 0.071	0.511
Fodder	- 0.008	0.027	**0.668**	0.017	- 0.205	- 0.114	0.345
Agroforestry	**0.628**	- 0.123	0.206	- 0.089	0.000	- 0.086	0.332
Anti-erosion	0.086	**0.450**	0.108	**0.305**	0.205	0.125	0.357

Note: Factor loadings > 0.30 in bold; PC1 = nutrient maintenance, PC2 = perennial cover crops & anti-erosion, PC3 = food & fodder, PC4 = fertiliser & anti-erosion, PC5 = weed control; source: own calculations

The first PC, "nutrient maintenance", focuses on SLM measures that reduce nutrient loss and help to close the nutrient cycle of a farm. PC2, "perennial cover crops & anti-erosion", encompasses SLM practices that once set up last for several production periods. They also share a communality that one of their main benefits is the reduction of soil loss and erosion. The third factor, "food & fodder", consists of SLM practices that produce food and fodder while simultaneously improving production yields and land quality. The fourth factor, "fertiliser & anti-erosion" consists of SLM technology mainly used to increase soil fertility or reduce soil loss. The last PC named "weed control" combines the farm practices "fallow" and "crop rotation" that are most often applied to control weed levels.

4.2 Adoption model

2SLS was used to test for endogeneity of the four social capital variables. Appendix 4 and 5 present the first and second stage of the 2SLS estimation for the four social capital variables respectively. The instruments in the first stage have the expected effect on social capital and are significant. However, the joint F-tests in the first stage presented in Table 4 show that the instruments do not pass the F-test threshold of 10 suggested by Staiger and Stock (1997), indicating that the correlations of the instruments and social capital are not strong enough in the first stage. Hence, a problem of weak instruments and biased 2SLS estimators is present. The null hypothesis of the Durbin and Wu–Hausman tests shown in Appendix 5 is that the social capital variables under consideration can be treated as exogenous. For PC1 up to PC4 both test statistics are not significant, so the findings fail to reject the null of exogeneity, while for PC5 both test statistics are significant at 10 %, suggesting that the social capital variables are endogenous. However, the Hausman test is invalid under weak instruments (Demko, 2012) and just-identified instrumental variable estimates with weak instruments tend to be highly unstable and imprecise (Angrist & Pischke, 2008). Due to the lack of appropriate instrumental variables, the social capital variables are therefore treated as exogenous in the adoption model but readers are cautioned that the appropriate interpretation of the results is one of statistical association and not necessarily structural causality.

Table 4: Test for weak instruments based on F-test

Variable	R-squared	Adj. R-squared	Partial R-squared	Robust *F*	Prob > *F*
Identifying (ProSOL participation)	0.520	0.456	0.105	3.990	0.004
Linking (Number of sales channels)	0.250	0.149	0.055	2.128	0.080
Bridging (Number of group memberships)	0.292	0.196	0.065	2.855	0.026
Bonding (Number of close family members)	0.357	0.270	0.091	3.408	0.011

Source: own calculations

SURE was used to test whether the decision to adopt different SLM practices is independent from one another. The Breusch-Pagan test of independence indicates that the residuals of the five equations in the adoption model are not significantly correlated (Chi^2 (10) = 5.417, p = 0.862). In other words, no efficiency is gained by estimating the equations as a system and they are instead estimated by OLS separately. Hence only these results are reported in Table 5 and will be further discussed. The results of the SURE are reported in Appendix 6.

The overall fitness of the PC1, PC2, PC4 and PC5 regression models are significant at a 5 % level, while the model of PC3 is only significant at a 10 % level. The R-square values are rather low, which was to be expected given the cross-sectional nature of the data and the attempt to predict human behaviour. A household's decision to implement perennial cover crops and anti-erosion measures (PC2) as well as SLM practices that maintain the nutrient level of the soil (PC1) is significantly influenced by linking social capital. With increasing numbers of distribution channels, households are encouraged to use improved residual management, agroforestry, aeschynomene histrix and anti-erosion measures but are discouraged from using excrements as organic fertiliser. A household's decision to adopt perennial cover crops and anti-erosion measures and fertiliser (PC2 & PC4) on their farms is significantly correlated with identifying social capital. Households that participate in the ProSOL programme are likelier to adopt pigeon pea, aeschynomene histrix, anti-erosion measures, manure and compost compared to non-participants, but are less likely to apply mineral fertilizer. Bridging social capital, measured by the number of village group memberships positively affects the use of organic fertiliser such as compost and excrements and encourages anti-erosion measures, but negatively influences the use of mineral fertiliser (PC4). The number of close family members as a proxy for bonding social capital does not significantly influence any of the five SLM components. A household's decision whether to grow fodder crop, intercrop cereal and legumes (PC3) or adopt weed control (PC5) by using crop rotation and fallow is not significantly correlated with a household's social capital. However, the quality of social capital is relevant for the decision to improve nutrient management. As expected, past experiences of conflicts with other farmers impede the adoption of improved residual management and agroforestry but surprisingly foster the adoption of excrements as fertiliser. Also unexpected is that involvement in past land disputes has the opposite effect on the implementation of nutrient management measures.

Table 5: Ordinary Least Square (OLS) results

Variables	PC1	PC2	PC3	PC4	PC5
Identifying (ProSOL participation)	0.352	0.848***	– 0.207	0.533*	0.227
	(0.268)	(0.292)	(0.318)	(0.313)	(0.283)
Linking (Number of sales channels)	0.330**	0.367**	0.138	– 0.267	0.129
	(0.142)	(0.155)	(0.169)	(0.166)	(0.150)
Bridging (Number of group memberships)	– 0.173	0.296	– 0.292	0.742***	0.073
	(0.165)	(0.179)	(0.195)	(0.192)	(0.174)
Bonding (Number of close family members)	0.012	– 0.037	– 0.019	0.007	0.019
	(0.028)	(0.030)	(0.033)	(0.032)	(0.029)
Conflict	– 0.451**	– 0.113	0.027	– 0.281	– 0.152
	(0.187)	(0.203)	(0.221)	(0.218)	(0.197)
Land dispute	0.399*	– 0.389	0.120	– 0.164	0.180
	(0.224)	(0.243)	(0.265)	(0.261)	(0.236)
Land quality	0.199**	0.021	0.223**	0.010	0.095
	(0.089)	(0.097)	(0.106)	(0.104)	(0.094)
Commune	0.214	– 0.156	– 0.165	– 0.411*	– 0.348*
	(0.193)	(0.210)	(0.228)	(0.225)	(0.203)
Farm size	– 0.019	0.054**	0.011	– 0.044*	0.007
	(0.020)	(0.021)	(0.023)	(0.023)	(0.021)
Livestock ownership	– 0.001	– 0.001	0.004	0.008*	0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Peul	– 0.807***	0.070	0.655**	0.107	– 0.452*
	(0.254)	(0.276)	(0.301)	(0.296)	(0.267)
Gando	– 0.476**	– 0.394*	0.382	– 0.064	– 0.036
	(0.216)	(0.236)	(0.257)	(0.252)	(0.228)
Other ethnicity	0.715	– 0.674	– 0.810	– 2.621**	– 1.590
	(1.063)	(1.157)	(1.260)	(1.240)	(1.121)
Gender	0.401	0.105	0.218	– 0.196	0.191
	(0.293)	(0.319)	(0.348)	(0.342)	(0.310)
Land tenure	0.110	– 0.374	0.132	0.419	– 0.316
	(0.239)	(0.260)	(0.283)	(0.279)	(0.252)
Participation	0.684***	0.387	0.064	– 0.131	0.381
	(0.243)	(0.264)	(0.288)	(0.283)	(0.256)
Warrantage	– 0.776	– 0.781	0.810	– 0.373	0.343
	(0.473)	(0.515)	(0.561)	(0.552)	(0.499)
Credit	0.424**	0.254	0.204	– 0.160	– 0.288
	(0.182)	(0.199)	(0.216)	(0.213)	(0.192)
Support	0.093	0.158	0.425	0.109	0.226
	(0.265)	(0.288)	(0.314)	(0.309)	(0.279)
Constant	– 1.263***	– 0.820*	– 1.194**	0.166	– 0.257
	(0.416)	(0.452)	(0.493)	(0.485)	(0.438)
Observations	161	161	161	161	161
R^2	0.46	0.35	0.17	0.21	0.21
Adjusted R^2	0.38	0.26	0.05	0.10	0.10
F (19, 141)	6.20	3.91	1.48	1.94	1.94
Prob > F	0.000	0.000	0.100	0.015	0.015

Note: When the models were calculated using robust standard errors the statistical summary was missing; however, since the smallholder farmers are homogenous in nature, homoscedasticity is assumed; standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; PC1 = nutrient maintenance, PC2 = perennial cover crops & anti-erosion, PC3 = food & fodder, PC4 = fertiliser & anti-erosion, PC5 = weed control; source: own calculations

A household's perception of its farm land quality is found to significantly determine its adoption behaviour regarding nutrient maintenance and growing food and fodder crops. Households who believe their soil is in a bad condition are more likely to grow pigeon pea, aeschynomene histrix, fodder crops, intercrop cereal and legume and build anti-erosion measure but are less likely to use animal manure as fertiliser than households unaware of the degradation problem. With regard to economic factors, the results indicate that the farm size significantly influences smallholders' adoption of perennial cover crops, anti-erosion measures and fertiliser application. While bigger farms are more likely to grow pigeon pea and aeschynomene histrix, build anti-erosion measures and use mineral fertiliser, smaller farms are more likely to use organic fertiliser but also build anti-erosion measures. Furthermore, livestock farming encourages the introduction of anti-erosion measures on the farm and the usage of excrements and compost as fertilisers but discourages the application of mineral fertiliser. The implementation of fallow and weed control by households is found to be significantly influenced by the farm's location, such that smallholder farmers living in Bembèrèkè are more hesitant to adopt these measures compared to households in Kandi. The results indicate that farmers' ethnicity significantly determines their adoption behaviour. The Peul apply less SLM practices such as improved residue management, agroforestry, fallow and crop rotation but use excrements as fertiliser, grow more fodder plants and intercrop cereal and legume compared to farmers who are part of the Bariba. Cultural affiliation to Gando is negatively correlated with the first and second SLM component. By contrast, farmers belonging to ethnic groups other than the Bariba, Peul and Gando are less likely to use mineral fertiliser but instead are more likely to use organic fertilisers and anti-erosion measures. Smallholder farmers who participate in development programmes and have access to credit have a higher chance of adopting improved residual management and agroforestry but are less likely to use excrements as fertiliser. Gender, land tenure, membership in an inventory credit system and agricultural advice are not found to be correlated with the adoption of any of the SLM components.

4.3 Effort model

In the case of the effort model, the control function approach was used to check for endogeneity of the social capital variables. While the instrumental variables were significant in the first stage regression (see Appendix 7), the residuals obtained are not significant in the ordered probit estimation (see Appendix 8), which signifies exogeneity of the social capital variables and excluding the residuals from the model is appropriate. Table 6 presents the estimated results and the marginal effects of the ordered probit model. The chi-squared statistic for the ordered probit model is 91.50 and is statistically significant ($p < 0.000$), indicating that the joint test of all slope coefficients equal to zero is rejected. Since the estimated coefficients of the ordered probit model only indicate the direction of a variable's effect, the marginal effects of changes in the regressors on the response probabilities were also estimated. The marginal effects are evaluated at the mean values of the explanatory variables. For example, there is a 2.2 % increase in the probability of adopting a sixth SLM measure for households with infertile land compared to farms with an average soil quality (moderately fertile). The ordered probit estimation results reveal that identifying social capital in the form of participation in ProSOL's extension programme and linking social capital represented by a household's number of sales channels has a positive effect on the number of SLM practices adopted. Households that participate in the ProSOL programme are on average 4.4 % more likely than non-participants to apply five or more SLM practices on their land. For every additional sales channel, the probability of applying more than four SLM practices increases on average by about 2.7 %.

Table 6: Results of the ordered probit model

Number of SLM practices adopted	Coefficients	SE	Average marginal effects								
			Prob ($Y_h = 1$)	Prob ($Y_h = 2$)	Prob ($Y_h = 3$)	Prob ($Y_h = 4$)	Prob ($Y_h = 5$)	Prob ($Y_h = 6$)	Prob ($Y_h = 7$)	Prob ($Y_h = 8$)	Prob ($Y_h = 9$)
Identifying (ProSOL participation)	0.624**	0.269	– 0.040*	– 0.070**	– 0.054**	– 0.014	0.037**	0.053**	0.031*	0.042*	0.013
Linking (Number of sales channels)	0.410***	0.142	– 0.026**	– 0.046***	– 0.035***	– 0.009	0.025**	0.035***	0.020**	0.027**	0.009
Bridging (Number of group memberships)	0.105	0.163	– 0.007	– 0.012	– 0.009	– 0.002	0.006	0.009	0.005	0.007	0.002
Bonding (Number of close family members)	0.014	0.027	– 0.001	– 0.002	– 0.001	– 0.000	0.001	0.001	0.001	0.001	0.000
Conflict	– 0.402**	0.188	0.026*	0.045**	0.035**	0.009	– 0.024**	– 0.034**	– 0.020*	– 0.027*	– 0.008
Land dispute	0.355	0.225	– 0.023	– 0.040	– 0.031	– 0.008	0.021	0.030	0.018	0.024	0.007
Land quality	0.254***	0.090	– 0.016**	– 0.028***	– 0.022***	– 0.006	0.015**	0.022***	0.013**	0.017**	0.005
Commune	– 0.406**	0.192	0.026*	0.045**	0.035**	0.009	– 0.024**	– 0.035**	– 0.020*	– 0.027*	– 0.008
Farm size	0.008	0.020	– 0.001	– 0.001	– 0.001	– 0.000	0.000	0.001	0.000	0.001	0.000
Livestock ownership	0.006	0.004	– 0.000	– 0.001	– 0.000	– 0.000	0.000	0.000	0.000	0.000	0.000
Peul	– 0.571**	0.254	0.036*	0.064**	0.049**	0.012	– 0.034**	– 0.049**	– 0.028*	– 0.038*	– 0.012
Gando	– 0.379*	0.212	0.024	0.042*	0.033*	0.008	– 0.023*	– 0.032*	– 0.019	– 0.025	– 0.008
Other ethnicity	– 0.779	1.051	0.050	0.087	0.067	0.017	– 0.047	– 0.067	– 0.039	– 0.052	– 0.016
Gender	0.387	0.299	– 0.025	– 0.043	– 0.033	– 0.008	0.023	0.033	0.019	0.026	0.008
Land tenure	0.007	0.235	– 0.000	– 0.001	– 0.001	– 0.000	0.000	0.001	0.000	0.000	0.000
Participation	0.484**	0.242	– 0.031*	– 0.054*	– 0.042*	– 0.011	0.029*	0.041*	0.024*	0.032*	0.010
Warrantage	– 0.021	0.470	0.001	0.002	0.002	0.000	– 0.001	– 0.002	– 0.001	– 0.001	– 0.000
Credit	– 0.179	0.181	0.011	0.020	0.015	0.004	– 0.011	– 0.015	– 0.009	– 0.012	– 0.004
Support	0.573**	0.262	– 0.036*	– 0.064**	– 0.049**	– 0.012	0.034*	0.049**	0.028*	0.038*	0.012
θ_1	– 0.692	0.452									
θ_2	0.236	0.428									
θ_3	0.963	0.434									
θ_4	1.916	0.451									
θ_5	2.644	0.466									
θ_6	3.359	0.479									
θ_7	3.814	0.491									
θ_8	4.829	0.600									
Number of observations	162										
LR $\mathcal{X}^2$ (19)	91.50										
Prob > $\mathcal{X}^2$	0.000										
Pseudo R^2	0.15										
Log likelihood	– 268.133										

Note: When the models were calculated using robust standard errors the statistical summary was missing; however, since the smallholder farmers are homogenous in nature, homoscedasticity is assumed; *** p<0.01, ** p<0.05, * p<0.1; marginal effects (dy/dx) are calculated at the mean for continuous variables and for discrete change from 0 to 1 for dummy variables; source: own calculations

On the contrary bridging and bonding social capital does not significantly influence the household's level of adoption. As expected, conflicts between farmers negatively affect the effort devoted to SLM. Farmers who have experienced conflicts with others in the past are on average around 2.6 % less likely to adopt five or more SLM practices. Furthermore, the results report that experiences of land dispute in the past does not significantly affect a household's SLM effort but so does their perception of the land quality. Households who believe their land is degraded tend to apply more SLM practices to their fields than farms who perceive to have a better soil quality. Also, the location of the farm is found to be an important factor in the use of SLM. Households located in the commune Bembèrèkè, which is generally speaking a less developed area than Kandi, significantly adopt fewer SLM practices. For example, the probability of applying more than four SLM measures decreases on average by about 2.7 % if a household is situated in Bembèrèkè. While the location of the farm is an important determinant, the farms size and ownership of farm animals does not seem to matter for the extent of SLM implementation. Regarding personal characteristics, it was found that households belonging to the ethnic group of Peul and Gando apply less SLM practices than Bariba farmers. For example, belonging to the ethnic group Peul decreases the probability of using five or more SLM practices on average by more than 3.7 %. A respondent's gender does not seem to be correlated with the number of adopted SLM practices. Surprisingly, land tenure ownership is not significant in the model either. Participation in development programmes and agricultural advice have a positive and significant coefficient. The probability of using five or more SLM practices increases by about 3.2 % and 3.7 % when a farmer receives development aid or agricultural advice respectively. Access to credit and membership in an inventory credit system does not seem to be relevant for a household's adoption extent decision.

5 Discussion

The results from the descriptive statistics provide information on the SLM adoption behaviour of smallholder farmers in northern Benin. They reveal that on average four out of the 14 SLM practices are adopted. When examining it more closely it becomes clear that three of the SLM practices are very popular, while almost half of the 14 SLM measures are adopted by less than 10 % of the households in the survey. This is in line with the findings in the literature (Kassie, Zikhali, Pender, & Köhlin, 2010) reporting low adoption rates of SLM technologies in Sub-Saharan Africa. It reinforces the relevance of the results of the regression models that provide an insight into how social capital and other control variables influence smallholders' adoption and the extent of adoption of various SLM practices, and helps to identify drivers and barriers to SLM adoption.

5.1 The role of social capital in SLM adoption

Regarding the influence of social capital on the adoption of the various SLM components, the results reveal heterogenous effects although prima facie the significant parameters have positive signs. This is due to the negative factor loading of the usage of manure and mineral fertiliser as part of PC1 and PC4 respectively. Hence, the first hypothesis that all four forms of social capital facilitate the adoption of SLM is rejected. Instead it is concluded that linking social capital in the form of participation in the ProSOL programme supports the adoption of improved residue management and agroforestry, while it hinders the use of manure as fertiliser. Along with identifying social capital in the form of different distribution channels, it also encourages planting of pigeon pea, aeschynomene histrix and installing anti-erosion measures. Bridging social capital in the form of memberships in village groups is found to facilitate the implementation of perennial cover crops and anti-erosion measures as well as the usage of compost and manure, but reduces the use of mineral fertiliser. This shows that the different forms of social capital complement each other in their impact: Identifying and linking social capital supports the adoption of durable measures such as agroforestry, anti-erosion and perennial crops as well as practices that rely on formal markets to buy seed such as planting pigeon pea and aeschynomene histrix. Bridging social capital helps to promote practices such as the use of manure and compost, which lack formal or perfect input markets and hence require personal connection and relationships with other farmers. This finding is comparable with those of Adong (2014) who found households' membership of farmers group to have a positive impact on the adoption of agricultural technologies, particularly organic fertilizers. The different effects of the diverse forms of social capital show the advantage of the presence of multiple social capital sources in the promotion of SLM. Several studies (Di Falco & Bulte, 2011; Teklewold et al., 2013; Warriner & Moul, 1992; Wossen et al., 2015) identified kinship network as an important determinant of agricultural technology adoption. However in the adoption models bonding social capital does not significantly influence households' adoption behaviour, which is similar to Kassie et al. (2013) findings in rural Tanzania where kinships did not significantly affect the adoption of soil and water conservation, legume intercrop, animal manure, chemical fertilizer, improved seeds and legume crop rotation either. The fact that the results of the present study differ to the majority of literature could be because only close family members (spouses and children) were considered for the family network variable while most other papers also included distant relatives who do not live in the same household. However, the expected benefits from kinship networks, such as informal insurance and access to credit, and the suspected disincentives due to kinship sharing obligations, may only apply across different households and are therefore not captured by the variable used in this study. Nevertheless, the changing sign of bonding social capital across the different SLM components confirms the expected ambiguous effect of kinship networks on SLM adoption.

The results from the effort model reveal that identifying and linking social capital have strong positive effects on the number of adopted SLM practices. This implies that social relationships formed in formal groups whose identity and function are linked to a common value or shared interest support the implementation of SLM practices. It also shows that for extensive SLM adoption it is important that farmers engage vertically along the supply chain and establish relationships with different traders. These results further indicate that formal social relationships, either based on common interest or on clearly defined roles, are useful in the promotion of SLM. On the contrary, more informal forms of social capital – here as bridging and bonding social capital – are found to not have a significant influence on the level of SLM adoption although a positive rather than a negative effect is suggested. The fact that formal networks are found to have stronger effects than informal social relationships is in line with the findings by Hunecke et al. (2017) but are contrary to the results of Bandiera & Rasul (2006) who found that social effects are larger among individuals with stronger social ties. The second hypothesis that all four forms of social capital enhance the extent of SLM adoption is therefore rejected, too.

Regarding the quality of social capital, the findings have shown that past conflicts with other farmers adversely affects the adoption of various SLM practices and the effort devoted to SLM in general. This could suggest that if households lack support and help from others and cannot benefit from friendly social relationships, SLM adoption is made difficult. Against the expectations the parameters of both the adoption and effort model imply a positive effect of the experience of land disputes in the past. One explanation for this could be that, after the issue is resolved land use rights are much clearer which increases the incentive for SLM adoption (compare Gebregziabher et al., 2014; Wollni et al., 2010). The finding that 72 % of the households were able to resolve their land disputes supports this presumption. Hence, the third hypothesis is also rejected and instead it is concluded that negative social capital – such as land disputes – dose not necessarily imply discouragement of SLM adoption.

5.2 The role of the other factors in SLM adoption

The results of the adoption and effort model as well as the descriptive statistics imply that adoption of SLM is lower among households who perceive their land as fertile or moderately fertile (this subgroup makes up 72 % of the sample size). This in line with earlier work by Ervin and Ervin (1982) and Rogers (1995) who identified the perception on soil erosion as a key first step in the decisions to adopt improved agricultural practices. The overall low adoption rate of SLM practices may therefore be partly due to the wrong perception of the land quality. In other words, some smallholders do not recognise the problem of land degradation and are therefore unaware of the necessity to solve it. The adoption of weed control measures and the extent of

SLM adoption also varies by commune which is likely to reflect unobservable spatial differences and location specific characteristics that encourage SLM adoption in Kandi but form barriers to extensive SLM in Bembèrèkè. The results further imply that households who have more land are encouraged to use SLM practices that need additional farm inputs (e.g., pigeon pea, aeschynomene histrix, mineral fertilizer, anti-erosion measures), while smaller farms prefer SLM methods that use existing or home-grown inputs (e.g., manure and compost). This suggests that shortage of land leads to intensification of agricultural production, using land-saving and yield-increasing strategies (compare Kassie et al., 2013). On the other hand, farm size is a proxy for wealth suggesting that wealthier households use more cost-intensive measures while poorer households rely on more labour-intensive but less costly practices. Ownership of livestock is found to support the use of animal manure, compost and anti-erosion measures, but decrease mineral fertilizer application. This shows that adoption is correlated with the existing farming practices and new SLM practices are implemented when they suit farm-specific characteristics. Hence farmers are more likely to adopt SLM practices that produce win–win benefits, such as intercropping of cereal and legumes or growing fodder crops which improve soil quality and yields but also serve as feed for livestock. The results indicate that a household’s ethnicity also plays a significant role in SLM adoption demonstrating the importance of cultural habits and traditions in determining farmers’ adoption behaviour. For example, smallholder farmers belonging to the ethnic group Peul, traditionally pastoralists, are generally less likely to adopt SLM measures, but they engage in practices that simultaneously enhance livestock production. This may lead to the conclusion that farming practices are linked to cultural backgrounds and that SLM adoption cannot be treated as a purely technical subject. It illustrates the need for SLM practices to be compatible with a households’ traditional way of living and in line with their needs in order to be accepted and successfully adopted. The significance of participation in development projects as well as access to credit and extension services underlines the dependency of smallholder farmers on external services to allow for SLM adoption. These results indicate that farmers make production and management decisions using information from technical advisors and trainers who serve as a catalyst for promoting adoption. However, this conclusion needs to be treated with caution as the result might be biased in cases where participants were selected according to criteria or where self-selection into a development project was possible. Furthermore, the findings show that access to credit proves useful for the adoption of some SLM practices. The results of the adoption and effort model suggest that land tenure, access to warrantage and gender do not significantly influence farmer’s adoption behaviour. However, the result on gender needs to be taken with caution since it only represents the gender of the respondent who is not always the head of the household or the deciding entity and hence the explanatory power of the gender variable is limited.

5.3 Limitations and future research suggestions

This study has an exploratory character. Due to the survey size, the survey method and the selection process of the survey area, this study is of limited representation of the smallholder farmer population in Benin. Hence most constraints of the secondary statistical analysis are related to the boundaries of the data.

The rather low R^2 values suggest that adoption of the various SLM technologies may be affected by additional factors not captured in the models. The characteristics of the SLM practices such as their profitability, associated risk, and ability to generate immediate benefits could also be included in the empirical analysis if one aims to capture a broader picture of the factors influencing adoption decisions. Future research could also consider including individual characteristics such as innovative behaviour, risk aversion, sympathy and teamwork skills.

Another improvement to the present study could be made by measuring adoption in more detail. Instead of only capturing adoption versus non-adoption, future research could account for the duration of adoption, the scale and scope of adoption or even record if a household abandoned a SLM practice. This approach would help to gain a more in-depth understanding of smallholders' adoption behaviours and patterns.

Although this study included several forms of social capital, it would be interesting to conduct a similar analysis using alternative measures of social capital and including additional dimensions such as trust and social norms. One concern is that some of the social capital variables used in this study might also capture the effects of other characteristics besides social capital. For example, participation in the ProSOL programme is used to measure the benefits gained from the interaction and knowledge exchange with other farmers, but could also include the advantages of receiving the extension service. This has the risk of overestimating the effect of social capital on SLM adoption. To improve the validity of the social capital analysis, one should try to use social capital indicators that purely capture network effects and isolate the effect of social capital.

Another limitation of the present study is the inability to establish a control for unobserved heterogeneity that may affect the social capital variables and the adoption of SLM practices. The causality and directionality of the relationship between social capital and SLM adoption therefore needs more analysis. This may require further research through methods such as valid instrumental variable regression, propensity score matching, randomised control trials or using panel data to evaluate the impact of social capital.

The results of the study, however, remain useful for providing insights as to how village groups, farmers activities and market networks are important means for SLM promotion and strategies to food security and poverty alleviation in an agriculture-dependent economy such as Benin.

6 Conclusion

The results of this study have shown that by identifying (participation in the ProSOL programme), linking (market network) and bridging (membership in village groups) social capital can positively (and in a very few cases negatively) influence the adoption of SLM practices. Bonding social capital (family network) was found to not significantly affect adoption. From these findings three main policy implications can be drawn.

Firstly, the study recommends that policies aiming to reduce land degradation and to promote SLM invest in the different forms of social capital. This can be done by supporting local community groups, by fostering the collaboration between smallholder farmers and external organizations, as well as promoting links between different farmer associations. These forms of networking can generate drivers to SLM adoption such as enhanced information flows, mutual learning and assistance when required.

Secondly, the results suggest the need for the strengthening of existing policies on institutional factors such as access to agricultural credit and improvement of market infrastructure and logistics. In this case social structures could also be used to improve local conditions. For example, farmers groups can take advantage of economics of scale when sharing transport to access inputs, co-use machinery needed for the new sustainable practice, or to overcome their labour resource constraints with labour-sharing arrangements. Loans could be given to a farmers group which then distribute the credit further to its members. This has the advantage that even the poorest farmers can have access to credit since the group act as a guarantor. Such social mechanisms may allow poor farmers and rural households to reduce costs and overcome poverty traps.

Lastly extension service is needed to teach farmers about the consequences of land degradation, how to recognize degraded land and how to prevent further depletion by applying SLM. SLM practices need to be adapted to plot and household specific characteristics, cultural aspects and the existing farming practice. Identifying and bridging social capital in the form of teamwork and farmers groups could facilitate the success of extension programmes and could be a first step towards farmer-to-farmer extension for SLM.

In conclusion, it is important to pay attention to social structures and how they operate in the respective communities during the formulation and implementation of SLM strategies. Social capital can support the adoption and use of SLM practices and hence policies that strengthen social structures and networks help to reduce land degradation and are therefore means to food security and poverty reduction.

Index of Appendices

Appendix

Appendix 1: Questionnaire

Section I. Informations générales sur l'enquêté(e) et son ménage

Date		**Heure de début**		**Heure de fin**	
Nom et pronom enquêté		**Téléphone**			
1.1 Principale occupation de l'enquêté (e)	Agriculture ☐ Elevage ☐ Commerce ☐ Autre ☐ ………………	**Heure début**		**Heure fin**	
1.2 Etes-vous le/la chef de ménage ?	Oui ☐ Non ☐ (si oui, aller à 1.4)	**1.21 Si non, quelle est votre filiation avec le chef de ménage**	Époux (se) ☐ Fils/fille ☐ Belle fille ☐ Mère chef ménage ☐ Autre ☐………..		
Comment s'appelle le chef de ménage ?		**1.22/3 Quel est son âge et son niveau d'instruction ?**	Age : Instruction (utilisez codes en bas): 0 1 2 3		
1.3 Vous sentez-vous en mesure de nous donner des informations sur votre ménage, son fonctionnement et sources de revenus ?			Oui ☐ (Si oui, passer à 1.4) Non ☐ (si non, mettre fin à l'enquête)		
1.4 Sexe	F ☐ M ☐	**1.5 Age (années)**	<18 ☐ 18-25☐ 26-35☐ 36-45☐ 55-65☐ 66-75 ☐ > 75☐		
1.6 Statut matrimonial	Célibataire ☐ Marié (e) ☐ Divorcé ☐ veuf (ve) ☐ Autre ☐ (…………...)				
1.7 Ethnie	Bariba ☐ Peulh ☐ Gando ☐ Autre ☐	**1.8 Religion**	Musulmane ☐ Chrétienne ☐ Traditionnelle ☐ Autre ☐………………		
1.9 Niveau éducation enquêté (e)	Aucune ☐ Primaire (au moins CM2) ☐ Secondaire 1 ☐ Secondaire 2 ☐ Ecole professionnelle ☐ Université ☐ Autre ☐ (…………...............................)				
1.11 Si applicable, nombre d'épouses		**1.12 Si applicable nombre d'enfants dans le ménage**			

Niveau éducation épouses	**A Age**	**B Scolarisation (code en bas)**	**1.13 Niveau éducation enfants**	**Tranches d'âges A 0-5 ans**	**B 6-15 ans**	**C > 15 ans**
1.141 Epouse 1			**1.131 Aucune**	Total : Filles :	Total : Filles :	Total : Filles :
1.142 Epouse 2			**1.132 Moins de CM 2**	Total : Filles :	Total : Filles :	Total : Filles :
1.143 Epouse 3			**1.133 A fait le CM 2**	Total : Filles :	Total : Filles :	Total : Filles :
1.144 Epouse 4			**1.134 Secondaire 1**	Total : Filles :	Total : Filles :	Total : Filles :
1.145 Epouse 5			**1.135 Secondaire 2**	Total : Filles :	Total : Filles :	Total : Filles :
			1.135 Université	Total : Filles :	Total : Filles :	Total : Filles :
			1.137 Alphabétisé	Total : Filles :	Total : Filles :	Total : Filles :
			1.137 Formations artisanales	Total : Filles :	Total : Filles :	Total : Filles :

Codes : 0 = Aucune 1 = Moins de CM2 2 = A fait le CM 2 3 = Secondaire niv. 1; 4 = Secondaire niv. 2 5=Autres -> préciser!

Section II. Mode d'éclairage, disponibilité services d'hygiène et assainissement

2.1 Quel type d'éclairage utilisez-vous dans le ménage ?	Electricité SBEE ☐ Groupe électrogène ☐ Panneaux solaires ☐ Lampions à pétrole ☐ Lampes à piles ☐ Autre (…………………….) ☐
2.2 De quels types d'installations sanitaires/ lieux d'aisance/toilettes disposez-vous ?	Aucune (brousse) ☐ WC traditionnels privés ☐ WC publics ☐ WC modernes ☐ Autres ☐ (……………….)
2.3 Matériaux de construction des maisons	Tente en paille ☐ Banco/terre de barre ☐ Briques de terres de barres ☐ Briques en ciment (bloc) ☐ Autres matériaux ☐ (…………………………..)
2.4 Coiffure/toiture des maisons	Paille ☐ Feuilles de tôle ☐ Dalle ☐ Autre (……………) ☐
2.5 Combien de pièces (chambre à coucher + salon) existent dans votre ménage ? combien parmi ces pièces ont un sol cimenté	Nombre bâtiments: Nombre total pièces : Nombre de pièces dont le sol est cimenté :
2.6 Quelles sources d'énergie domestique utilisez-vous pour la cuisson ?	Bois de chauffage ☐ Charbon ☐ Réchaud (pétrole) ☐ Biogaz ☐ Foyers améliorés ☐ Autre ☐ (……………………...)

2.7 De quel(s) moyen(s) d'accès à l'information/communication disposez-vous dans le ménage ?	Postes radio ☐ Poste téléviseur ☐ Téléphone portable ☐ Autre ☐ (…………………)

Section III. Production, dépenses et revenus agricoles de l'enquêté(e) et de son ménage

Section III.1. Données sur l'exploitation du ménage				
3.11 Quelle est la superficie totale de l'exploitation gérée par votre ménage?				
3.12 Quelle est la superficie de la portion de terre que vous, en tant qu'individu gérez?				
3.13 Est-ce que quelqu'un dans le ménage a eu recours à de la main d'œuvre pour travailler dans son lopin de terre au cours de ces deux dernières années ?	Oui ☐ Non ☐			
3.14 Si oui, qui a fait recours à cette main-d'œuvre ?	Chef ménage ☐	Femmes ☐		
3.15 Quel type de main d'œuvre a été sollicité ?	Famille ☐	Solidarité ☐	Main d'œuvre salariée ☐	Autre ☐…… ……..
3.16 Pour quelles cultures avez-vous eu recours à la main-d'œuvre ?	Coton ☐ Vivrières ☐ Autres ☐ (…………………)			
3.17 Pour quelles activités précises ?	Désherbage ☐ Labour ☐ Semis ☐ Récolte ☐ Transport récolte ☐ Autres ☐ (……………………………………..)			
3.18 Quel était le mode de paiement ?	Argent liquide ☐ Sac de vivres ☐ Autres ☐…………….			
3.19 Le travail portait sur combien d'hectares ?		**3.20Combien de manœuvres avez-vous sollicité ?**		
3.21 Combien de jours les manœuvres ont travaillé pour vous ?		**3.22 Combien vous a coûté en tout cette main d'œuvre (en FCFA?**		

Section III.2. La production agricole et sources de revenus agricoles (au cours de la saison passée)	
3.23 Quelles sont les principales sources de revenus de votre ménage ?	Agriculture ☐ Elevage ☐ Commerce ☐ Transf. Produits agricoles ☐ Artisanat ☐ Autres ☐

Si agriculture, pour chaque spéculation que vous cultivez, veuillez nous aider avec les questions suivantes

Cultivez-vous du… ?	**A Qui cultivent ces spéculations ?**	**B Surface emblavée (ha)**	**C Récolte (sacs)**	**Vente produits agricoles (FCFA)**		**Achat pour assurer les besoins alimentaires du ménage**	
				D Quantité (sacs)	**E Prix unit. par sac**	**F Quantité (sacs)**	**G Prix unit./ sac (FCFA)**
3.231 Riz	Hom ☐ Fem ☐						
3.232 Mais	Hom ☐ Fem ☐						
3.233 Sorgho	Hom ☐ Fem ☐						
3.234 Igname	Hom ☐ Fem ☐						
3.235 Arachide	Hom ☐ Fem ☐						
3.236 Soja	Hom ☐ Fem ☐						
3.237 Haricot	Hom ☐ Fem ☐						
3.238 Coton	Hom ☐ Fem ☐		(en tonnes)	Bénéfices net annuel (FCFA) :			
3.239	Hom ☐ Fem ☐						
3.240	Hom ☐ Fem ☐						

Section III.3. Possession, acquisition, vente et perte d'animaux d'élevage entre 2015 et 2016 ?

Si élevage, veuillez nous aider avec les questions suivantes

Elevage	**A Nombre**	**B Propriété des animaux**	**Acquisition entre 2015 et 2016 (FCFA)**		**Vente entre 2015 et 2016 (FCFA)**		**G Animaux morts (2015-2016)**
			C Nombre	**D Prix unitaire**	**E Nombre**	**F Prix unitaire**	
3.31 Bovin		Hom ☐ Fem ☐					
3.32 Ovin		Hom ☐ Fem ☐					
3.33 Caprin		Hom ☐ Fem ☐					

3.34 Porcins		Hom ☐ Fem ☐					
3.35 Volaille		Hom ☐ Fem ☐					

3.4 Avantages de l'élevage	**A** Bovins	Culture attelée ☐	Revenus financiers ☐	Alimentation☐	Déjections ☐	Autres ☐ …………
	B Ovin/caprins	Culture attelée ☐	Revenus financiers ☐	Alimentation☐	Déjections ☐	Autres ☐ …………
	C Volailles	Culture attelée ☐	Revenus financiers ☐	Alimentation☐	Déjections ☐	Autres ☐ ………….
	D Autres	Culture attelée ☐	Revenus financiers ☐	Alimentation☐	Déjections ☐	Autres ☐ ………….

Section III.4. Activités génératrices de revenus			
Si vous faites de la transformation des produits agricoles, veuillez nous aider avec les questions suivantes			
3.5 Y-a-t-il quelqu'un qui transforme et commercialise ces produits dans votre ménage ?	**A Si oui, produits dérivés de la transformation**	**B Revenu /semaine (FCFA)**	**C Acteurs (voir codes en bas)**
3.51 Riz ☐Oui ☐ Non*			
3.52 Mais ☐Oui ☐ Non			
3.53 Sorgho ☐Oui ☐ Non			
3.54 Igname ☐Oui ☐ Non			
3.55 Arachide ☐Oui ☐ Non			
3.56 Soja ☐Oui ☐ Non			
3.57 Haricot ☐Oui ☐ Non			
Autre 1 (préciser)………………………………			
Autre 2 (préciser)………………………………			
3.6 Quelles autres sources de revenus avez-vous ?	3.61 Petit commerce divers ☐		
	3.62 Artisanat ☐		
	3.63 Production vente de tabac ☐		
	3.64 Autres ☐………		
*Codes : * 0 = non 1 = chef ménage 2 = Epoux 2 = Epouses ; 3 = Enfant 4 = Autres (Préciser svp)*			

Section IV. Accès aux intrants agricoles : Engrais, insecticides, herbicides, semences vivriers

4.1 Est-ce que quelqu'un dans votre ménage a utilisé l'un ou l'autre des types intrants agricoles suivant au cours de la saison agricole passée ?	Oui ☐ Non ☐
Si vous avez répondu « oui » à la question 4.1, veuillez s.v.p. répondre aux questions ci-dessous. Sinon, passez directement à la question 5.1	
4.2 Informations sur les produits utilisés pour cultiver et/ou améliorer les rendements agricoles	

Intrants agricoles	**A Utilisé pour culture de…**	**B Quantité achetée (indiquer unité)**	**C Prix unitaire (indiquer unité)**	**D Quantité utilisée suffisante ?**	**E Si non, pourquoi vous n'avez pas utilisé la quantité qu'il faut ?**
4.21 Herbicide	Coton ☐ Vivriers ☐			Oui ☐ Non ☐	
4.22 Insecticide	Coton ☐ Vivriers ☐			Oui ☐ Non ☐	
4.23 Engrais	Coton ☐ Vivriers ☐			Oui ☐ Non ☐	
4.24 Semences	Coton ☐ Vivriers ☐			Oui ☐ Non ☐	

Section V. Circuits d'acquisition/commercialisation des intrants agricoles et produits de récolte

5.1 Par quels canaux vendez-vous, en général, vos produits agricoles ?	**5.2 Par quels canaux achetez-vous, en général, les produits agricoles ?**	**5.3 Par quels canaux achetez-vous ces intrants ?**		
		A Semences	**B Engrais**	**C Pesticides**
Contacts personnels ☐ Commerçant niv. village ☐ Intermédiaires niv. village ☐ Intermédiaires niv. commune ☐ Marché village ☐ Marché arr./com.☐ Marchés nat ☐ Exportation ☐ Autres ☐ …………………………….	Contacts personnels ☐ Commerçant niv. village ☐ Intermédiaires niv. village ☐ Intermédiaires niv. commune ☐ Marché village ☐ Marché arr./com.☐ Marchés nat Exportation ☐ Autres ☐ ………	CARDER ☐ SONAPRA ☐ Marché village ☐ Marché arrond. ☐ Autre ☐ ………....... ……………	CARDER ☐ SONAPRA ☐ Marché vill.☐ Marché arrond. ☐ Autre ☐ ……………. ……………...	CARDER ☐ SONAPRA ☐ Marché vill. ☐ Marché arrond. ☐ Autre ☐ …………. ……………… …..
Notes additionnelles :				

Section VI. Accès aux facteurs de production et matériels agricoles

6.1 Est ce toutes les terres exploitées par les membres du ménage sont la propriété du ménage ?	Oui ☐ Non ☐	**Si non, combien d'hectares de terres appartiennent au ménage ?**	……… ha
6.2 Comment avez-vous acquis ces terres sur lesquelles votre ménage cultive aujourd'hui ?	Héritage ☐ Achat ☐ Prêt ☐ Don ☐ Époux/se ☐ Location ☐ Métayage ☐ Autre ☐ *(………………………..)*		

6.3 Est-ce que la portion de terre que vous cultivez en tant qu'individu vous appartient ?	Oui ☐ Non ☐	**6.4 Comment l'avez-vous obtenu ?**	Héritage ☐ Achat ☐ Prêt ☐ Don ☐ Époux/se ☐ Location ☐ Métayage ☐ Autre ☐ (……………...)

6.5 Si métayage, expliquez le deal		**6.6 Si achat montant / hectare?**		**6.7 Si location, coût/hectare**	

6.8 Lesquels de ces matériels/équipements agricoles ou moyens de transport *possédez*-vous présentement ou louez-vous ?

Matériel/ équipement fonctionnels	**Nombre**	**Acquisition (< 3 ans)?**	**Prix unitaire (FCFA)**	**Location**			
				A autres pers.	**Revenus location**	**d'autres pers.**	**Coût location**
6.81 Vélo		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	
6.82 Moto		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	
6.83 Charrues		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	
6.84 Motoculteur		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	
6.85 Tracteur		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	
6.86 Charrette à traction animale		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	
6.87 Tricycle		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	
6.88 Véhicule		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	
6.89 Autre		Oui☐ Non☐		Oui☐ Non☐		Oui☐ Non☐	

6.9 Quelle(s) était(ent) la/les principale(s) source(s) financière(s) pour les acquisitions ci-haut ?	
Bénéfice vente de coton ☐ Bénéfice vente de produits vivriers ☐ Vente de bovins ☐ Vente de ruminants ☐ Crédits ☐ Autre ☐……………………………………………………	

Section VII. Connaissances et pratiques des mesures de la gestion durable des terres (GDT)

7.1 Comment trouvez-vous la qualité des terres exploitées par votre ménage ?	Fertiles ☐	Peu fertiles ☐	infertiles ☐	Erodées par endroit ☐	Très érodées ☐
7.2 Comment trouvez-vous la qualité des terres que vous exploitées en tant qu'individu ?	Fertiles ☐	Peu fertiles ☐	infertiles ☐	Erodées par endroit ☐	Très érodées ☐
7.3 Quelles seraient les causes de cette dégradation, selon vous ?					
7.4 Lesquels de ces technologies GDT appliquez-vous en ce moment ou avez-vous expérimentées par le passé afin de faire face aux problèmes de dégradation de vos terres ?					

Technologie GDT	A Actuellement appliquée ?	B Appris comment ?
7.41 **Engrais minéraux**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.42 **Jachère**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.43 **Rotation de cultures** (préciser cultures) ………………………….	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.44 **Association céréales-légumineuse** (préciser cultures) ……	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.45 **Enfouissement résidus de récolte**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.46 **Culture pois d'angole**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.47 **Culture de Mucuna**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.48 **Culture *Stylosanthes guianensis***	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.49 **Culture *Aeschynomene histrix***	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.50 **Utilisation compost**	Oui ☐ Non ☐ Abandonnée ☐ **Si oui,** en tas ? ☐ en fosse ? ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………………
7.51 **Utilisation des déjections animales**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.52 **Culture fourrages** (préciser espèces)…………………….	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.53 **Agroforesterie** (préciser espèces)……………………..	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.54 **Mesures anti-érosive** (préciser mesures)	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.55 **Autre1**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.56 **Autre2**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………
7.57 **Autre3**	Oui ☐ Non ☐ Abandonnée ☐	Parent ☐ ONG/Projet ☐ CARDER ☐ Autre ☐ …………………………

7.6 Si utilisation des déjections animales, quelle est l'origine de la fumure utilisée?			Animaux de l'enquêté ☐	Collecte agriculteurs voisins ☐
Collecte campements environnants ☐	Contrat de parcage avec éleveurs locaux ☐	Contrat de parcage avec les transhumants ☐	☐ Autre *(précisez s.v.p)*	
7.7 Quel est le mode de transport de la fumure vers les champs ?				
À pied ☐ Vélo/Moto ☐	Charrette bovine ☐	Tricycle ☐	Véhicule ☐	Autres ☐ ………………….

Section VIII. Autres facteurs supportant la production agricoles et l'adoption de technologies GDT

A. Accès à l'eau potable et d'abreuvement									
A8.1 Lesquelles de ces sources d'eau utilisez-vous pour couvrir les besoins en eau potable de votre ménage surtout en saison sèche ?									
Puit privé	☐	Barrage, mares, rivières	☐	Puits publics	☐	Pompes villageoises	☐	Autres *(……………)*	☐
A8.2 Si pompe villageoise, combien de bidons d'eau (bidon jaune de 25 litres) puisez-vous en moyenne par jour ?						**A8.3 Combien payez-vous pour un bidon d'eau (FCFA)?**			
A8.4 Combien de temps passez-vous en moyenne pour puiser de l'eau en saison sèche ?									
moins de 30 min ☐		30 min à 1 h ☐		1 à 2 h ☐		2 à 4 h ☐		4h et plus ☐	
A8.5 Lesquelles de ces sources d'eau utilisez-vous pour l'abreuvement de votre cheptel en saison sèche ?									

Puit privé	☐	Barrage, rivières, mares	☐	Puits publics	☐	Pompes villageoises	☐	Autres (…………)	☐

A8.6 Si pompe villageoise, combien de bidons d'eau jaune (de 25 litres) puisez-vous par jour pour vos animaux ?	

A8.7 Faites-vous du jardinage ou de la culture irriguée ? (si non, passer à la sous-section B)	Oui ☐ Non ☐	**A8.71 Si oui, que cultivez-vous ?**	Maraîchers ☐ Riz ☐ Autres ☐……………………

A8.8 Lesquelles de ces sources d'eau utilisez-vous pour irriguer vos cultures ?									
Barrages	☐	Cours d'eau, mares	☐	Puits publics	☐	Pompes villageoises	☐	Autres (………………)	☐

A8.81 Si pompe villageoise, combien de bidons d'eau (bidon jaune de 25l) puisez-vous en moyenne par jour ?	
B. Accès aux soins et services de santé	
B8.1 Y a-t-il eu un décès dans ce ménage au cours de ces cinq (05) dernières années	Oui ☐ Non ☐
B8.11 Si oui, qui est décédé(e) ?	Enfant moins de 5 ans ☐ jeune 6-15 ans ☐ Jeune femme moins 35 ans ☐ Autres ☐
B8.2 Avez-vous (ou un membre de votre ménage) eu des ennuis de santé au cours des 2 dernières années?	Oui ☐ Non ☐
B8.21 Si oui, comment l'avez-vous soigné ou comment vous vous êtes soigné ?	
Médecine traditionnelle ☐ Automédication ☐ Unité villageoise de santé (UVS) ☐ Centre de *santé*/hôptial ☐ Autre☐…….....................	
B8.22 Si automédication ou médecine traditionnelle, pourquoi n'avez-vous pas fait recours au centre de santé ou l'UVS ?	
Pas centre santé dans village ☐ Manque de moyens financiers ☐ Maladie bénigne ☐ Maladie jugée occulte ☐ Autre ☐ ……….	
B8.23 Si vous avez eu recours à un CSC ou à un hôpital, combien vous ont coûté les soins fournis ?	

B8.3 Comment avez-vous mobilisé l'argent nécessaire pour subvenir à vos soins et services de santé ?						
Réserves financières	☐	Solidarité famille/proche	☐	Vente urgente de céréales	☐	Autres
Prêt auprès d'un membre famille/tiers	☐	Vente de bovins	☐	Vente autres animaux	☐	

B. Sécurité alimentaire	
B8.4 Est-ce que votre ménage a rencontré des difficultés particulières au cours des deux dernières années pour couvrir les besoins alimentaires du fait de la disette, catastrophe naturelle ou autres facteurs ?	Oui ☐ Non ☐
B8.41 Si oui, quelles en étaient les causes principales ?	
B8.42 Comment avez-vous résolu cette situation ?	
C. Organisation villageoise : Groupements et associations	
C8.1 Êtes-vous membre d'un ou plusieurs groupements villageois?	Oui ☐ Non ☐ — **Si oui, combien ?**
C8.2 Quels sont ces groupements ?	
C8.3 Quelles sont les conditions pour intégrer le (s) groupement (s) ?	Pratiquer même activité agricole ☐ Payer frais adhésion ☐ Payer part sociale ☐ Autre ☐ …………………………
C8.4 Quels avantages trouvez-vous à être membre de ce (s) groupements ?	Appartenance à un groupe ☐ Solidarité ☐ Formations/appui conseils ☐ Bénéficier dons/matériels des projets/ONG ☐ Facilite accès aux microcrédits ☐ Tontine ☐ Autre☐ ....
C8.5 Comment appréciez-vous les interactions/relations des membres du groupe ?	Très bonne ☐ Moyen ☐ Pas bonne☐
C8.6 Est-ce que votre groupement a au moins une fois bénéficier de la formation d'un projet/programme ?	Oui ☐ Non ☐
C8.61 Si oui, combien de fois un ou les membres de votre groupement qui sont allés suivre une formation sont revenus vous faire une restitution et vous former à votre tour ?	
C8.7 Lesquels parmi ces acteurs suivants ont grandement contribué aux formations, connaissances et compétences que vous avez reçues des projets/programmes	
Encadreurs CARDER ☐ Techniciens ONG/projets ☐ Producteurs pilotes ☐ Membres du groupement ☐ Autres ☐ ………………………………………………………	
C8.8 Si vous n'êtes pas membre d'un groupement, pourquoi n'avez-vous pas adhéré à un ?	Éviter problèmes/disputes ☐ Pas d'avantages ☐ Pas de groupement ☐ Refus d'admission/rejet ☐ Coût cotisations élevées ☐ Autre ☐ …………..........

D. Identification des types de conflits dans les villages	
D8.1 Avez-vous déjà fait face à des conflits liés à vos terres agricoles (conflits fonciers) ?	Oui ☐ Non ☐
Ces conflits sont définitivement résolus ou encore actuels ?	Définitivement résolu ☐ Actuel ☐

D8.11 Si oui, quelle était la cause de ce conflit ?	Dispute titre propriété ☐ Dispute limites propriété ☐ Autres ☐………......................
D8.12 Quels acteurs sont/étaient en conflits ?	Bariba ☐ Gando ☐ Peulh ☐ Autres ethnies ☐………….
	Membres même famille ☐ Membres familles différentes ☐ Autres acteurs ☐……………..........
D8.13 Comment avez-vous résolu le conflit ?	Entente niveau famille ☐ Entente niveau village ☐ Entente niveau CA ☐ Gendarmerie ☐ Tribunal ☐ Autres ☐ …………………

D8.2 Avez-vous déjà fait face à des conflits de type agriculteurs-éleveurs ?	Oui ☐ Non ☐	**Si oui, fréquence**	1-2 fois/an ☐ 1 fois ces 2-3 dernières années ☐ 1fois ces 4-5 dernières années ☐ Autres ☐ ……………...........................
D8.21 Quels acteurs étaient en conflits?	Agric.- élev. locaux ☐	Agric.- transh. béninois ☐	Agric.-transh. internationaux ☐
D8.22 Quelles sont en général les causes de ces conflits ?	Dégâts animaux dans les champs ☐ Occupation zone de pâturage/ d'abreuvement ☐ Querelles personnelles ☐ autres ☐……............		
D8.23 Comment avez-vous résolu le conflit ?	Entente niveau famille ☐ Entente niveau village ☐ Entente niveau CA ☐ Gendarmerie ☐ Tribunal ☐ Autres ☐ …………………		

E. Accès aux services de warrantage et de microcrédits			
E8.1 Faites-vous personnellement du warrantage ?	Oui ☐ Non ☐ Abandonné ☐	**E8.11 Si oui, produits warrantés ?**	Mais ☐ Riz ☐ Soja ☐ Autre ☐………………….
E8.2 Quels avantages trouvez-vous dans le warrantage ?	Réduction pertes post-récolte ☐ Microcrédits ☐ sécurité alimentaire du ménage ☐ Accès à d'autres formes de crédits ☐ Autres ☐ …………………………………		
E8.3Si abandonné, pourquoi ?			
E8.4 Avez-vous pris un crédit agricole au cours des dernières 5 années ?	Oui ☐ Non ☐ Abandonné ☐	**Si oui, quel montant ?**	
E8.5 Où est-ce que vous allez aller chercher le crédit alloué ?	Village ☐ Arrondissement ☐ Chef-lieu commune ☐ Autre ☐		
E8.6 Comment évaluez-vous les conditions d'accès aux crédits ?	Très contraignantes ☐ Abordables ☐ Faciles ☐		
E8.7 Si non ou abandon, pourquoi ?	Ne veut pas de crédit ☐ Manque structure/agents crédits au niveau village ☐ Taux intérêt élevé ☐ Conditions d'accès contraignantes ☐ Autres ☐…………………………………		

Section IX. Activités ProSOL et participation aux projets/programmes de la GDT

Section 9-A Focus sur la mise en œuvre du ProSOL dans le village cible			
A9.1 Avez-vous entendu parler du projet ProSOL?	Oui ☐ Non ☐	**Si non, avez-vous entendu parler d'un nouveau projet qui s'occupe de la restauration des terres dégradées ?**	Oui ☐ Non ☐
A9.2 Si oui, comment avez-vous eu des informations sur le ProSOL?	Ami/voisin dans le village ☐ Radio ☐ Agents d'ONG ☐ Encadreurs CARDER ☐ Autres ☐ ……………………………….		
A9.3 Êtes-vous membre d'une des classes de producteurs du ProSOL ?	Oui ☐ Non ☐		
A9.4 Si oui, comment avez-vous été abordé/choisi pour participer aux activités du projet ProSOL ?	Sélection parmi volontaires ☐ Identifié par encadreur CARDER ☐ Identifié par agents projets ☐ Autres ☐ ……………………………		
A9.5 Quelles technologies de la GDT mettez-vous en œuvre dans le cadre du ProSOL?			
A9.6 Aviez-vous des expériences par rapport à certains de ces technologies ?	Oui ☐ Non ☐		
A9.7 Si oui, lesquels ?			

Section 9-B Accès aux conseils agricoles/renforcement de capacités et suivi des exploitations	
B9.1 Aviez-vous travaillé (ou présentement encore) avec un projet de développement ?	Oui ☐ Non ☐
B9.2 Sous quelles formes aviez-vous participé à ces projets ou reçu leurs appuis?	Producteur pilote/ relais ☐ Formation en salles ☐ Dons des intrants ☐ Formation et expérimentation sur champs ☐ dons matériels ☐ Visite et appui dans nos champs ☐ Autres ☐ ………………………
B9.3 Comment aviez-vous pris connaissance des activités de ces projets?	Ami/voisin dans le village ☐ Radio ☐ Agents d'ONG ☐ Encadreurs CARDER ☐ Autres ☐ …………………………
B9.4 Comment aviez-vous été abordé/choisi pour participer aux activités du projet) ?	Sélection parmi volontaires ☐ Identifié par encadreur CARDER ☐ Identifié par agents projets ☐ Autres ☐ ……………………….
Section 9-C Appui conseils à la production vivrière	
C9.1 Dans la production des produits vivriers, est ce qu'il y a des structures et agents de terrains qui vous soutiennent en conseils agricoles ?	Oui ☐ Non☐
C9.11 Si oui, quelles sont ces structures ?	Agents d'ONG/projets ☐ Producteur pilote/autres agriculteurs formés ☐ Encadreurs CARDER ☐ Autres ☐………………….
C9.2 A quelle fréquence, les encadreurs du CARDER vous conseillent/appuient dans la production vivrière ?	Mensuel ☐ Trimestriel ☐ Saisonnier ☐ Quasi permanent ☐
C9.3 Depuis combien de temps bénéficiez-vous de leur conseils dans la production agricole ?	
C9.4 Si non, pourquoi n'avez-vous pas de soutien de ces agents?	

Appendix 2: Description of the sample

Around 83 % and 80 % of the people who were interviewed in Kabanou and Sinawongourou respectively were male. On average the education level among the respondents in Kabanou was slightly higher than in Sinawongourou. Whereas 84 % of the respondents from Kabanou have no school education, only 61 % of the Sinawongourou sample have never attended school, and at least 20 % have attended primary school compared to 2 % in Kabanou. The distribution across the remaining education levels in both villages is very similar with around 9 % and 8 % benefiting from secondary education and 4 % and 2 % having a university degree or higher education for Sinawongourou and Kabanou respectively. Most of the respondents named agriculture as their main occupation (about 84 %) while 8 % practice livestock farming and 4 % are mainly engaged in trade or another 4 % in other businesses. The average sample farm is about 8 hectare and has 25 farm animals. However, the high standard deviation for the ownership of livestock (27.31) implies large differences between farmers with respect to the number of farm animals. 81 % of the interviewed households state that they own the rights to their land whereas 19 % either rent the land or sharecrop. Although both intervention villages are characterised by high degrees of land degradation, on average respondence rate their household's land as moderately fertile. About 73 % of the respondents state that their land is either fertile or moderately fertile while about 8 % report moderately or very eroded soil conditions. The remaining 19 % perceive the land quality as infertile. In Sinawongourou 8 households are using the warrantage system, while in Kabanou no such credit system exist end hence none of the households in Kabanou use this form to access credit. But in both villages around 40 % of the households received credit in the last 5 years. In Sinawongourou 23 % of the households had participated in development projects and had made use of agricultural advisory service, while in Kabanou 32 % of the households had been involved in development project and 8 % received extension service.

Appendix 3: Description of the other variables

One of the explanatory factors considered in the empirical analysis is the household's perception of the *land quality* (1 equals fertile up to 5 which equals very eroded) which is expected to be positively related with the adoption and number of SLM practices performed on the farm. It is assumed that a household is more likely to adopt SLM if it perceives the degradation problem.

With respect to sociodemographic variables, a household's ethnicity as well as the respondents' gender has been considered. With respect to the variable *ethnicity* four categories were established: *Bariba*, *Peul*, *Gando* and *other ethnicity*, whereby Bariba is used as the reference category. The effect of a household's ethnicity on its SLM adoption decision is difficult to hypothesize a priori and is therefore ambiguous. Previous studies have identified differences in agricultural practices between the three ethnic groups (Baco, Biaou, & Lescure, 2007; P. F. A. Moumouni, 2012). While agriculture in the form of crop production is the dominant occupation for the Bariba, the Peul are primarily known to be pastoralists. The Gando are a group of slave descendants and are socially placed at the margins of Benin's society (Hahonou, 2011). Therefore, depending on a household's ethnic background, the agricultural practices and the motivation to invest in SLM technologies are likely to differ. Regarding gender it has been argued that in Sub-Saharan Africa gender specific constraints exist, such that women have less access to crucial farm resources (land, labour, and cash) (De Groote & Coulibaly, 1998; Quisumbing, Brown, Feldstein, Haddad, & Peña, 1995) and education (Ndiritu, Kassie, & Shiferaw, 2011). It is obvious that these constraints are barriers to SLM adoption so that women are hypothesized to adopt less. *Gender* is specified as dummy variable equal to 1 for male and 0 for female.

Economic factors are considered in the analysis by including variables for the farm location and the farm size as well as the number of farm animals owned by a household. To account for local conditions and regional differences between farms (e.g., road access), the dummy variable *commune* equal to 0 for households in the commune of Kandi and equal to 1 for households in the commune of Bembèrèkè is included in both the adoption and effort model. Due to the fact that Kandi has generally better local conditions than Bembèrèkè, the sign of the location variables is expected to be negative. The variable *farm size* is used as a proxy of household wealth. The hypothesised positive direction of influence in both the adoption and effort model is based on the assumption that wealthier households are better able to withstand the risks associated with the adoption of new agricultural practices and may be more able to finance the purchase of the required inputs, such as fertiliser and improved seeds compared to poorer households. The variable *livestock ownership* measures the number of farm animals owned by a household. The hypothesized effect of this variable is ambiguous. On the one hand crop-livestock production system are common in developing countries, where livestock serve as source of manure and draft power, ease capital/cash constraints and crop enterprises generate fodder for livestock (Gebregziabher et al., 2014). On the other hand livestock may compete with labour and a stronger specialization into livestock away from cropping may reduce the economic impact and incentives to implement SLM (compare Shiferaw & Holden, 1998).

Institutional influences are addressed by including the variables land tenure, participation, warrantage, credit and support. The variable *land tenure* is specified as a dummy variable equal to 1 if the land is owned by the household and equal to 0 for all other land use arrangements. It is assumed that an ownership title of the land gives the household security and thus incentives for long term investments including SLM. Therefore, a positive impact of land ownership on the adoption and extent of SLM is expected. The dummy variable *participation* captures whether or not a household member participated in development projects. It is coded equal to 1 for participation and 0 otherwise. It is hypothesized that, households who participated in promotional and awareness enhancing activities and/or received additional external support from programmes are more likely to adopt SLM and devote more effort to it. The dummy variables *warrantage* and *credit* indicate whether or not a household is a member of an inventory credit system and has received credit in the last five years respectively. Since improved technologies are often associated with high input and equipment costs (Muzari, Gatsi, & Muvhunzi, 2012) access to credit and financing schemes can be of vital help for rural people starting new SLM initiatives (Liniger et al., 2011). Receiving state official advice from the Centre d'Action Régional pour le Développement Rural (CADER) or other extension service (*support*) is hypothesized to have a positive influence on adoption and level of SLM adoption because these forms of external support are a major source of technical information and assistance for farmers. A household's contact with extension agents allows them greater access to information on how and when to use a new technology (Abdulai & Huffman, 2014) and creates more opportunities to participate in demonstration tests of good farming practices.

Appendix 4: First stage of 2SLS

Variables	Identifying (ProSOL participation)	Linking (sales channels)	Bridging (membership)	Bonding (family members)
Land dispute	0.107	0.092	0.064	- 0.459
	(0.076)	(0.143)	(0.120)	(0.638)
Conflict	- 0.062	- 0.096	- 0.069	0.667
	(0.053)	(0.117)	(0.094)	(0.528)
Land quality	0.045	- 0.042	- 0.056	0.200
	(0.029)	(0.058)	(0.045)	(0.296)
Commune	0.111	0.502***	0.050	- 0.495
	(0.083)	(0.137)	(0.141)	(0.776)
Farm size	- 0.000	- 0.002	0.013	0.067
	(0.007)	(0.014)	(0.012)	(0.070)
Livestock ownership	- 0.001	0.001	- 0.001	0.028***
	(0.001)	(0.002)	(0.002)	(0.010)
Peul	- 0.143**	0.043	0.118	1.816**
	(0.071)	(0.149)	(0.131)	(0.816)
Gando	- 0.055	0.261**	0.184*	1.817***
	(0.066)	(0.119)	(0.103)	(0.648)
Other ethnicity	- 0.184**	0.621***	- 0.339**	0.160
	(0.092)	(0.210)	(0.152)	(0.804)
Gender	- 0.024	- 0.164	0.083	- 0.763
	(0.066)	(0.160)	(0.141)	(0.959)
Land tenure	- 0.040	0.431***	- 0.018	0.043
	(0.054)	(0.108)	(0.126)	(0.695)
Participation	0.441***	- 0.019	0.135	0.116
	(0.082)	(0.133)	(0.112)	(0.660)
Warrantage	0.428**	0.139	0.077	1.373
	(0.177)	(0.304)	(0.209)	(1.114)
Credit	- 0.050	0.079	0.163*	0.070
	(0.058)	(0.111)	(0.098)	(0.501)
Support	- 0.155*	0.022	0.087	0.296
	(0.086)	(0.131)	(0.190)	(0.948)
Heard of ProSOL	0.158**	0.008	0.168	0.363
	(0.064)	(0.110)	(0.110)	(0.639)
Sinawongourou Peul	0.157	0.336**	- 0.090	- 0.271
	(0.100)	(0.162)	(0.153)	(0.943)
Cotton	0.054	0.305*	0.258**	- 0.665
	(0.067)	(0.158)	(0.117)	(0.652)
Motorcycle	0.082*	0.077	0.0751	1.351***
	(0.048)	(0.076)	(0.089)	(0.463)
Constant	- 0.112	0.693***	0.131	3.108**
	(0.092)	(0.210)	(0.199)	(1.342)
Observations	161	161	161	161
R^2	0.52	0.25	0.29	0.36
Adjusted R^2	0.46	0.15	0.20	0.27
F (19, 141)	10.67	11.94	21.09	14.74
Prob > F	0.000	0.000	0.000	0.000

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; PC1 = nutrient maintenance, PC2 = perennial cover crops & anti-erosion, PC3 = food & fodder, PC4 = fertiliser & anti-erosion, PC5 = weed control; source: own calculations

Appendix 5: Second stage of 2SLS

Variables	PC1	PC2	PC3	PC4	PC5
Identifying (ProSOL participation)	- 0.351	2.657	2.599	0.863	- 2.312
	(1.593)	(1.928)	(2.114)	(1.903)	(2.897)
Linking (Number of sales channels)	0.985	- 0.661	- 0.133	- 0.411	- 0.498
	(0.956)	(1.148)	(1.279)	(1.084)	(2.055)
Bridging (Number of group memberships)	0.234	- 0.526	- 0.521	0.480	2.584*
	(0.869)	(1.137)	(1.506)	(0.784)	(1.549)
Bonding (Number of close family members)	0.0901	- 0.232	- 0.205	0.047	- 0.123
	(0.129)	(0.185)	(0.230)	(0.186)	(0.268)
Land dispute	0.446	- 0.571	- 0.251	- 0.159	0.362
	(0.312)	(0.470)	(0.420)	(0.264)	(0.501)
Conflict	- 0.445*	- 0.072	0.172	- 0.342	0.110
	(0.229)	(0.233)	(0.335)	(0.236)	(0.375)
Land quality	0.250*	- 0.092	0.096	- 0.023	0.315
	(0.131)	(0.150)	(0.179)	(0.137)	(0.235)
Commune	0.059	0.050	- 0.243	- 0.360	- 0.263
	(0.286)	(0.329)	(0.348)	(0.339)	(0.520)
Farm size	- 0.040	0.096	0.025	- 0.045	- 0.012
	(0.039)	(0.090)	(0.045)	(0.032)	(0.052)
Livestock ownership	- 0.005	0.010	0.013	0.007	0.007
	(0.008)	(0.009)	(0.012)	(0.010)	(0.017)
Peul	- 1.058**	0.673	1.345*	0.102	- 0.571
	(0.489)	(0.678)	(0.789)	(0.761)	(0.896)
Gando	- 0.902*	0.444	0.894	- 0.021	- 0.157
	(0.493)	(0.635)	(0.813)	(0.811)	(1.064)
Other ethnicity	0.492	- 0.290	- 0.355	2.607***	- 0.516
	(0.764)	(0.892)	(1.300)	(0.939)	(1.667)
Gender	0.362	0.142	- 0.020	- 0.151	- 0.299
	(0.420)	(0.422)	(0.598)	(0.403)	(0.720)
Land tenure	- 0.210	0.136	0.328	0.511	- 0.121
	(0.552)	(0.634)	(0.699)	(0.577)	(1.134)
Participation	0.932	- 0.273	- 1.157	- 0.268	1.214
	(0.701)	(0.882)	(1.071)	(0.766)	(1.345)
Warrantage	- 0.675	- 1.108	- 0.045	- 0.530	1.349
	(0.669)	(0.783)	(1.079)	(0.603)	(1.170)
Credit	0.236	0.621*	0.380	- 0.104	- 0.704
	(0.253)	(0.365)	(0.393)	(0.376)	(0.514)
Support	- 0.101	0.625	0.999*	0.191	- 0.469
	(0.444)	(0.602)	(0.602)	(0.597)	(0.834)
Constant	- 2.114*	0.796	- 0.212	0.225	0.172
	(1.188)	(1.473)	(1.613)	(1.436)	(2.555)
Observations	161	161	161	161	161
R^2	0.31	.	.	0.18	.
Wald $\mathcal{X}^2$ (19)	334.01	179.86	135.11	1363.60	224.67
Prob > $\mathcal{X}^2$	0.000	0.000	0.000	0.000	0.000
Durbin $\mathcal{X}^2$	1.963	3.484	4.657	0.912	9.539**
Wu-Hausman F-test	0.434	0.775	1.165	0.191	2.395*

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; PC1 = nutrient maintenance, PC2 = perennial cover crops & anti-erosion, PC3 = food & fodder, PC4 = fertiliser & anti-erosion, PC5 = weed control; source: own calculations

Appendix 6: Seemingly uncorrelated regression (SUR) results

Variables	PC1	PC2	PC3	PC4	PC5
Identifying (ProSOL participation)	0.352	0.848***	- 0.207	0.533*	0.227
	(0.251)	(0.273)	(0.298)	(0.293)	(0.265)
Linking (Number of sales channels)	0.330**	0.367**	0.138	- 0.267*	0.129
	(0.133)	(0.145)	(0.158)	(0.155)	(0.140)
Bridging (Number of group memberships)	- 0.173	0.296*	- 0.292	0.742***	0.073
	(0.154)	(0.168)	(0.183)	(0.180)	(0.163)
Bonding (Number of close family members)	0.012	- 0.037	- 0.019	0.007	0.019
	(0.026)	(0.028)	(0.031)	(0.030)	(0.027)
Conflict	- 0.451***	- 0.113	0.027	- 0.281	- 0.152
	(0.175)	(0.190)	(0.207)	(0.204)	(0.184)
Land dispute	0.399*	- 0.389*	0.120	- 0.164	0.180
	(0.209)	(0.228)	(0.248)	(0.244)	(0.221)
Land quality	0.199**	0.021	0.223**	0.010	0.095
	(0.084)	(0.091)	(0.099)	(0.098)	(0.088)
Commune	0.214	- 0.156	- 0.165	- 0.411*	- 0.348*
	(0.180)	(0.196)	(0.214)	(0.210)	(0.190)
Farm size	- 0.019	0.054***	0.011	- 0.044**	0.007
	(0.018)	(0.020)	(0.022)	(0.022)	(0.019)
Livestock ownership	- 0.001	- 0.001	0.004	0.008*	0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Peul	- 0.807***	0.070	0.655**	0.107	- 0.452*
	(0.237)	(0.258)	(0.281)	(0.277)	(0.250)
Gando	- 0.476**	- 0.394*	0.382	- 0.064	- 0.036
	(0.203)	(0.220)	(0.240)	(0.236)	(0.214)
Other ethnicity	0.715	- 0.674	- 0.810	2.621**	- 1.590
	(0.994)	(1.082)	(1.179)	(1.160)	(1.049)
Gender	0.401	0.105	0.218	- 0.196	0.191
	(0.275)	(0.299)	(0.326)	(0.320)	(0.290)
Land tenure	0.110	- 0.374	0.132	0.419	- 0.316
	(0.224)	(0.243)	(0.265)	(0.261)	(0.236)
Participation	0.684***	0.387	0.064	- 0.131	0.381
	(0.227)	(0.247)	(0.269)	(0.265)	(0.240)
Warrantage	- 0.776*	- 0.781	0.810	- 0.373	0.343
	(0.443)	(0.482)	(0.525)	(0.516)	(0.467)
Credit	0.424**	0.254	0.204	- 0.160	- 0.288
	(0.171)	(0.186)	(0.202)	(0.199)	(0.180)
Support	0.093	0.158	0.425	0.109	0.226
	(0.248)	(0.270)	(0.294)	(0.289)	(0.261)
Constant	- 1.263***	- 0.820*	- 1.194***	0.166	- 0.257
	(0.389)	(0.423)	(0.461)	(0.454)	(0.410)
Observations	161	161	161	161	161
R^2	0.46	0.35	0.17	0.21	0.21
$\mathcal{X}^2$	134.57	84.90	32.20	42.14	42.07
Prob > $\mathcal{X}^2$	0.000	0.000	0.030	0.002	0.002

Note: When the models were calculated using robust standard errors the statistical summary was missing; however, since the smallholder farmers are homogenous in nature, homoscedasticity is assumed; standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; PC1 = nutrient maintenance, PC2 = perennial cover crops & anti-erosion, PC3 = food & fodder, PC4 = fertiliser & anti-erosion, PC5 = weed control; source own calculations

Appendix 7: First stage results of the control function approach

Variables	Identifying (ProSOL participation)	Linking (sales channels)	Bridging (membership)	Bonding (family members)
Land dispute	0.619	0.092	0.037	- 0.243
	(0.432)	(0.125)	(0.105)	(0.640)
Conflict	- 0.577	- 0.098	- 0.072	0.668
	(0.465)	(0.113)	(0.095)	(0.575)
Land quality	0.281	- 0.024	- 0.054	0.235
	(0.200)	(0.053)	(0.044)	(0.265)
Commune	0.474	0.475***	0.030	- 0.288
	(0.557)	(0.142)	(0.119)	(0.708)
Farm size	0.007	0.001	0.015	0.074
	(0.041)	(0.012)	(0.010)	(0.063)
Livestock ownership	- 0.014	0.001	- 0.001	0.028**
	(0.009)	(0.002)	(0.002)	(0.011)
Peul		- 0.004	0.112	1.775**
		(0.155)	(0.130)	(0.784)
Gando	- 0.460	0.236*	0.183*	1.756***
	(0.420)	(0.120)	(0.101)	(0.612)
Other ethnicity		0.124	- 0.360	0.025
		(0.448)	(0.376)	(3.176)
Gender		- 0.051	0.080	- 0.610
		(0.180)	(0.151)	(0.945)
Land tenure	0.263	0.375***	- 0.039	- 0.020
	(0.628)	(0.133)	(0.112)	(0.668)
Participation	1.726***	- 0.063	0.148	0.038
	(0.390)	(0.120)	(0.101)	(0.608)
Warrantage	3.214***	0.133	0.053	1.288
	(1.188)	(0.272)	(0.228)	(1.370)
Credit	- 0.643	0.061	0.171*	0.044
	(0.409)	(0.105)	(0.089)	(0.534)
Support	- 0.506	0.011	0.047	0.203
	(0.527)	(0.149)	(0.127)	(0.750)
Heard of ProSOL	1.888***	0.009	0.186*	0.372
	(0.564)	(0.113)	(0.095)	(0.582)
Sinawongourou Peul	0.835	0.310*	- 0.117	
	(0.703)	(0.170)	(0.143)	
Sinawongourou Bariba				0.370
				(0.861)
Cotton	0.139	0.277*	0.267**	- 0.737
	(0.593)	(0.142)	(0.119)	(0.735)
Motorcycle	0.896**	0.057	0.045	1.260***
	(0.366)	(0.083)	(0.070)	(0.434)
Constant	- 4.295***	0.687***	0.166	2.847**
	(1.105)	(0.227)	(0.191)	(1.297)
Observations	117	170	169	165
R^2		0.23	0.30	0.35
Adjusted R^2		0.13	0.21	0.26
F		2.35	3.36	4.08
Prob > F		0.002	0.000	0.000
LR $\mathcal{X}^2$ (16)	77.28			
Prob > $\mathcal{X}^2$	0.000			
Pseudo R^2	0.52			

Note: When the models were calculated using robust standard errors the statistical summary was missing; however, since the smallholder farmers are homogenous in nature, homoscedasticity is assumed; standard errors in parentheses; standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; source: own calculations

Appendix 8: Second stage results of the control function approach

Number of SLM practices adopted	Coefficients	SE
Explanatory variables		
Identifying (ProSOL participation)	0.603	0.928
Linking (Number of sales channels)	- 0.111	1.050
Bridging (Number of group memberships)	- 0.007	1.101
Bonding (Number of close family members)	- 0.019	0.158
Conflict	- 0.740***	0.270
Land dispute	0.205	0.305
Land quality	0.289**	0.127
Commune	- 0.006	0.359
Farm size	0.005	0.034
Livestock ownership	0.006	0.009
Peul		
Gando	0.051	0.556
Other ethnicity		
Gender		
Land tenure	- 0.004	0.578
Participation	0.608	0.417
Warrantage	0.203	0.600
Credit	- 0.273	0.339
Support	0.390	0.352
Residue (ProSOL participation)	0.074	0.399
Residue (Number of sales channels)	0.294	1.059
Residue (Number of group memberships)	0.183	1.121
Residue (Number of close family members)	0.073	0.158
Threshold parameters		
θ_1	- 2.332	1.307
θ_2	- 1.087	1.234
θ_3	- 0.400	1.232
θ_4	0.637	1.239
θ_5	1.405	1.244
θ_6	2.224	1.246
θ_7	2.598	1.250
θ_8	3.686	1.297
Model summary		
Number of observations	113	
LR $\mathcal{X}^2$ (20)	54.15	
Prob > $\mathcal{X}^2$	0.000	
Pseudo R^2	0.13	
Log likelihood	- 181.908	

Note: When the models were calculated using robust standard errors the statistical summary was missing; however, since the smallholder farmers are homogenous in nature, homoscedasticity is assumed;
*** p<0.01, ** p<0.05, * p<0.1; source: own calculations

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