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Uptake of Soil and Water Conservation Technologies in West Africa: A Case Study of the Office de la Haute Vallée du Niger (OHVN) in Mali

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Abstract

This report provides a descriptive analysis of the uptake of Soil and Water Conservation (S&WC) technologies based on a survey undertaken in a degraded area of Mali, the Office de la Haute Valeé du Niger (OHVN). A total of 531 rural households were interviewed from 26 villages, with the objective of characterizing, identifying and evaluating potential environmental, socioeconomic, institutional and technological constraints to uptake of S&WC technologies, comparing users and nonusers of the technologies at the village, household and plot levels. The study revealed that 40% of the households were using S&WC technologies in the OHVN zone. A range of factors such as endowments in livelihood assets and transforming structures such as markets and institutions, access to roads, suitability of soil for cotton, prevalence of input product markets, access to fertilizers on credit and others were the drivers of uptake. Adoption was concentrated in the southern part of the OHVN zone, where OHVN's Natural Resource Management Program had been involved in disseminating technologies. At the household level, users of S&WC technologies were found to have more livelihood assets than nonusers. Most farmers reported high productivity gains ranging from 20% to 60% from these technologies. Overall, 75% of the user households were reported to have accumulated more assets and become more food secure.

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Abbreviations and Acronyms

CLUSA	Cooperative League of the United States of America
CMDT	Compagnie Malienne pour le Développement des Textiles
CNQREG	Censored Quantile Regression Model
DFID	Department for International Development
FAO	Food and Agriculture Organization of the United Nations
FCFA	Franc de la Communauté Financière Africaine (West African monetary unit)
GIS	Geographic Information System
GPS	Global Positioning Systems
GMM	Generalized Method of Moments
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IER	Institut d'Economie Rurale
INRM	Integrated Natural Resource Management
NGO	Non-Governmental Organization
NRM	Natural Resource Management
OHVN	Office de la Haute Vallée du Niger
OLS	Ordinary Least Squares
PRA	Participatory Rural Appraisal
S&WC	Soil and Water Conservation
TLU	Tropical Live Units
UNCTAD	United Nations Conference on Trade and Development
USAID	United States Agency for International Development

Summary

This report summarizes the results of a survey on the uptake of soil and water conservation (S&WC) technologies in a degraded area of Mali, the Office de la Haute Vallée du Niger (OHVN). Twenty-six villages were purposely chosen for the survey, from which a total of 531 rural households were randomly selected and interviewed. Data were collected through focus group interviews at the village level and structured questionnaires at the household level. The major objectives of the survey were to characterize, identify and evaluate potential environmental, socioeconomic, institutional and technological constraints to uptake of S&WC technologies, identify the level of uptake and the determinants of uptake and assess the factors that would explain household perception of welfare changes.

The survey results indicated that a range of factors govern the uptake of soil and water conservation methods, first among which is the technology dissemination process. The natural resource management (NRM) program of OHVN has been actively involved in disseminating S&WC methods south of theOHVN zone, a region suitable for cotton production. It was found that the technologies widely used in this region, such as stone bunds, stone lines, living hedges, vegetative bands and branch barriers, were the very ones that had been disseminated. Secondly, endowments in livelihood assets and transforming structures such as markets and institutions were drivers of technology uptake. For instance, uptake was relatively high in places where there were better roads, better soils for cotton production, markets, access to fertilizers through credit provided by OHVN and institutions dealing with health, education and farmers' organizations.

At the household level, the survey results showed that 40% of the households adopted at least one S&WC technology. Stone lines and stone bunds were the most widely adopted technologies. Vegetative bands, wood barriers and live fences were adopted by more than 5% of the households. Adoption was concentrated in the southern part of the OHVN zone where the NRM program has widely disseminated technologies. Users of S&WC technologies were found to have more livelihood assets than nonusers. On average, user households had a larger work force, more educated members, owned more land, livestock and agricultural equipment, and had more cash income and consumable assets than nonusers. Most farmers reported high productivity gains ranging from 20 to 60% from these technologies, with the exception of the half-moon technology.

Results at the plot level revealed a similar trend. Households applied at least one S&WC technology in 20% of their cultivated plots. Stone lines were used on 10% of the plots, and stone bunds on 5%. User farmers applied more fertilizers per ha (53 kg) than nonusers (30 kg). Fertilizer application varied significantly by crop: it was high in high-value crops such as cotton and maize and low in others. Farmers own an average of 3 plots, and grow a range of crops including sorghum, millet, cowpea, groundnut, maize, rice and cotton. They plant a single crop in half of their plots. Plots largely differ in their characteristics but in this respect there was no significant difference between users and nonusers except in their perception of fertility and production levels.

Households' perceptions of change or productivity levels did not necessarily tally with the estimated yields of major crops. Except in sorghum and cotton, there were no significant yield differences between users and nonusers of S&WC technologies. This raises the question whether there are any productivity gains derived from using these technologies. This question is difficult to address because of the lack of baseline data to assess the situation before and after the project. It may well be that productivity in some areas was very low and that the use of soil and

water conservation led to a significant increase. This may have been the case in the south of the OHVN zone where water erosion is a more important factor than in the other OHVN regions. In addition, lack of monitoring and evaluation of technologies makes it difficult to assess trends in yields.

Overall, 75% of the user households were reported to have accumulated more assets and become more food secure during 1995-2002. In addition, more than 80% of the households said there was a large improvement in health, education and access to potable water. However, it is difficult to attribute changes in overall well-being to soil and water conservation technologies alone. Many other interventions may have played a role too.

The households most likely to use S&WC technologies are those which cultivate cash crops (such as cotton); they tend to be better equipped, generate more liquidity from crop, livestock or off-farm income, and have a better perception of plot fertility. They also tend to be younger and relatively better educated. In addition, households with large plot areas, private plots, and those with plots in sloping areas are more likely to use soil and water conservation technologies. Policies that improve farmers' education, facilitate access to credit to purchase agricultural equipment and provide alternative livelihood options will enhance the uptake of soil and water conservation technologies.

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This report would not have been possible without the financial support of ICRISAT and USAID through the US-AIARC linkage grant under MSU reference No. 61-9842. We also had the support of the OHVN management who facilitated our introductions and enhanced our understanding of their development interventions. We acknowledge the contributions of Dr K Palanisami and other reviewers, and the assistance of OHVN field agents and enumerators. We are indebted to farmers in the OHVN zone, who tirelessly responded to our questions. The data entry assistance provided by Abdoulaye Amadou and Rahamatou Mahamane Hambali (Global Theme on Institutions, Markets, Policy and Impacts) are also gratefully acknowledged.

I. Introduction

Mali is a large, landlocked country in West Africa, occupying 1,240,000 km^2 and having a population of 11.6 million. It is among the least developed countries in the world with a human development index of 0.333 and per capita gross national income (GNI) of US$ 360. More than 80% of the population above 15 years is illiterate. Life expectancy is low (48 years). More than 72% of the population lives below the international poverty line, ie, on less than US$1 a day (UNCTAD 2005).

Due to the high population growth rate (2.9% per year), per capita land availability is declining. Fallow periods are getting shorter, and farmers are having to cultivate even marginal land. Soil productivity is declining. In effect, nutrient losses in Mali were estimated in 1983 at 7.7 kg N ha^{-1}, 2.2 kg P ha^{-1}, and 8.32 kg K ha^{-1}; on average, farmers in Mali use less than 9.5 kg ha^{-1} of plant nutrients compared to 200 kg ha^{-1} in western Europe (Stoorvogel and Smaling 1990; FAOSTAT 2006). Agricultural intensification, which requires the use of improved technologies, has barely occurred. Production increases have been the result of expansion of cultivated area rather than intensification. Sorghum and pearl millet are the main staple cereals, accounting for 74% of the total cereal area and 53% of the cereal production. However, since 1984, pearl millet yields have been declining at the rate of 1.02% per year and sorghum yields by 1.16% (FAOSTAT 2006). This is largely due to low and variable rainfall and the limited use of improved technologies such as improved varieties and soil and water conservation methods.

There is growing consensus that restoration of soil fertility and conservation of soil and water resources are the starting points for agricultural transformation and development in West Africa (Bekunda et al. 1997; Borlaug and Dowswell 1994; Dyson 1995; Quinones et al. 1997; Smaling et al. 1997; Stoorvogel and Smaling 1990; Bationo and Baidu-Forson 1997). This consensus is supported in part by mounting evidence that traditional soil, water and nutrient management practices are not enough to attain the 4% annual growth rate in agricultural production needed to meet the food requirements of the rapidly growing population. In the past, production increases were met through expansion of cultivated area. However, with land getting scarcer, production increases will now have to be achieved through higher productivity. This requires, among other steps, accelerated uptake of improved soil and water management in order to reduce erosion and improve soil moisture content, restoring soil nutrients through the use of organic and inorganic fertilizers, and adopting improved cultivars.

Substantial progress has been reported in the development and testing of technologies that have the potential to promote agricultural intensification (Bationo and Baidu-Forson 1997; Bationo et al. 1998; Ndjeunga and Bantilan 2005; Sanders et al. 1996). However, despite the efforts made to promote these technologies, their adoption by farmers remains limited (Ndjeunga and Bantilan 2005; De Jager et al. 1998; Bationo and Baidu-Forson 1997; Bationo et al. 1998; Baidu-Forson and Bationo 1992; Scoones 1998; Kaya et al. 2000; Lamers 1995; Diouf et al. 1998). Researchers have identified a range of technical, socioeconomic, institutional and policy constraints to technology uptake. For instance, extension recommendations are sometimes inappropriate or ineffective. The promotion of manure application without warning that it may reduce yields under limited rainfall is a case in point (Affholder 1994). Likewise, use of mineral fertilizers is widely promoted by research and development organizations as a blanket recommendation irrespective of zonal, climatic and geological diversity (Diouf et al. 1998). Often a technology that worked well under on-station circumstances has not been adapted to farmers' conditions (Lamers et al. 1998).

Economic benefits are widely recognized as a driver of technology adoption (Zougmoré et al. 2004; Baidu-Forson and Bationo 1992; Lamers 1995; Lamers et al. 1998; Shiferaw and Freeman 2003). In effect, adoption of S&WC technologies has been higher for cash crops than subsistence crops (Savadogo et al. 1998; Diarra 2000). This is consistent with findings (Mortimore and Harris 2005) that recommend market development and improvement of market access as remedies against soil degradation. Short-term yield losses (or a lack of gain) combined with high discount levels due to poverty and market failures are important limitations (Shiferaw and Holden 2002). Poverty is correlated with limited use of S&WC technologies: adoption is lower among resource-poor farmers (Ouédraogo 2005; Savadogo et al. 1998; Mortimore and Harris 2005; Lamers 1995; Ndjeunga and Bantilan 2005; Schlecht and Buerkert 2004). Labor constraints can inhibit uptake and are often the most severe in poor households (Lamers 1995;Ouédraogo 2005).

Production and market risks are factors limiting private investments and risk adversity largely influence adoption of technologies by farmers (De Jager et al. 1998; Mortimore and Harris 2005; Ndjeunga and Bantilan 2005). Farmers face a range of production, market, policy and institutional risks, and are not likely to invest if yields are uncertain, product prices fluctuate widely, land is perceived to be nonsecure or if the government's direct or indirect intervention preempts farmers' profit or utility. Other studies have shown that access and availability of inputs are significant constraints to adoption too (De Jager et al. 1998; Bationo and Baidu-Forson 1997; Diarra 2000; Savadogo et al. 1998; Baidu-Forson 1999).

Farmers' perception of productivity gains and exposure to information on technologies have been reported to play a major role in adoption (Adesina and Baidu-Forson 1995; Baidu-Forson 1999). Shiferaw and Holden (1998) found that availability of information, increase in land-man ratios and anticipation of higher returns by using S&WC measures are drivers of uptake of soil and land management technologies in Ethiopia. In rural Uganda, results from household surveys have shown that land tenure and access to credit were of low importance in soil management, but education, ownership of livestock and involvement in nonfarm activities significantly reduced soil nutrient depletion (Nkonya et al. 2004). Baidu-Forson and Bationo (1992) showed that availability of manure, relative input costs, opportunity costs of funds, soil deficiencies, and labor and manure transportation were the main factors influencing adoption in Niger. Limited productivity gains, poorly functioning institutions, lack of information, poor exposure of farmers to technologies and absence or malfunctioning of markets were found to be factors limiting uptake of improved technologies in the semi-arid tropics of West Africa (Ndjeunga and Bantilan 2005).

In Mali, despite the apparent progress made by researchers in developing and adapting these integrated technologies, factors driving uptake remain poorly understood and documented. In the OHVN zone, in particular, several S&WC technologies have been promoted by OHVN, but the empirical evidence on the level of adoption is weak. Evidence has been gathered suggesting widespread adoption of a range of natural resource management technologies in this zone over the past ten years (Kelly 2003; Kelly and Gregersen 2003). These include technologies such as inorganic fertilizers, rock lines, branch barriers, small dikes, vegetative bands, compost pits, etc. However, there has been no systematic effort to assess the level of uptake or the factors influencing uptake of S&WC technologies. Information about successful adoption of integrated practices remains largely anecdotal, making it difficult to design programs to promote and sustain adoption.

Using the sustainable livelihood framework, this study will identify and evaluate potential environmental, socioeconomic, institutional and technological drivers of uptake of S&WC technologies, identify the level of uptake, assess household perception of welfare changes and identify factors explaining thereof. Section 2 of this report provides a description of the study area followed by the NRM program of the OHVN zone in Section 3. Section 4 presents the analytical framework based on the livelihood framework and Section 5 the methodology and sampling frame. The results and discussion of the survey can be found in Section 6 while Section 7 concludes with research and development implications.

2. Description of the Study Area

The Office de la Haute Vallée du Niger (OHVN) zone, stretches out along the administrative circles of Kati, Kangaba and Koulikoro. It includes about 770 villages with an estimated 520,000 inhabitants cultivating about 38,000 farms occupying 204,000 ha. In 1999, the OHVN zone produced 5.5% of Mali's cotton, 2.3% of its traditional cereals and 3.5% of its rice. The zone is characterized by severe soil erosion associated with deforestation. It is very close to the capital, Bamako.

In the 1990s, the need to identify options to resolve production and environmental constraints in this zone was felt urgently, prompting donor support for the initiation of the Natural Resource Management Program of the OHVN. The zone falls within the Sudanian and Sahelian zones with annual rainfall ranging from a low 700 mm in the north to 1200 mm in the south. It ends in the dry Sahelian zone in the north and borders the Guinea-Sudan zone in the south. The soils (predominantly ferriluvisols) are characterized by high erosion and degradation with deforestation being a contributing factor (Kelly 2003). Sorghum, cotton, millet and maize dominate the production systems. Cereals are by far the major source of energy in the farmers' diet. This is supplemented by the cultivation of legume crops such as groundnut and cowpea. Irrigated rice, fruits and vegetables are grown in the wet areas.

Families rely heavily on agriculture for their livelihood. Cereals are mainly cultivated by men, whereas vegetables (tomato, onion, cucumber, eggplant, okra, etc.) and groundnut are generally considered the domain of women. Cotton is also a major cash crop grown especially in the southeastern part of the OHVN zone. The use of purchased inputs such as pesticides and inorganic fertilizers is higher in the cotton zone than elsewhere in Mali with the exception of the irrigated perimeter of the Office de la Haute Vallée du Niger. Households engage in nonfarm activities including petty brick making, sale of wood, charcoal and handicrafts. Emigration to urban areas during the agricultural off-season is very common, particularly among men.

The OHVN zone can be divided into four areas on the basis of soil type and topography, agricultural potential, quality of infrastructure and institutional make-up (Fig. 1). Zone I, the area south of the Niger river, is the main focus of the OHVN and is a predominantly sloped area with light lateritic soils. Deforestation has caused significant erosion problems, requiring anti-erosive measures. It is the major cotton producing area and has benefited from interventions by NGOs and rural development projects. Farmers here are well-informed, trained in modern technologies and understand the need to use improved practices and modern inputs such as fertilizer.

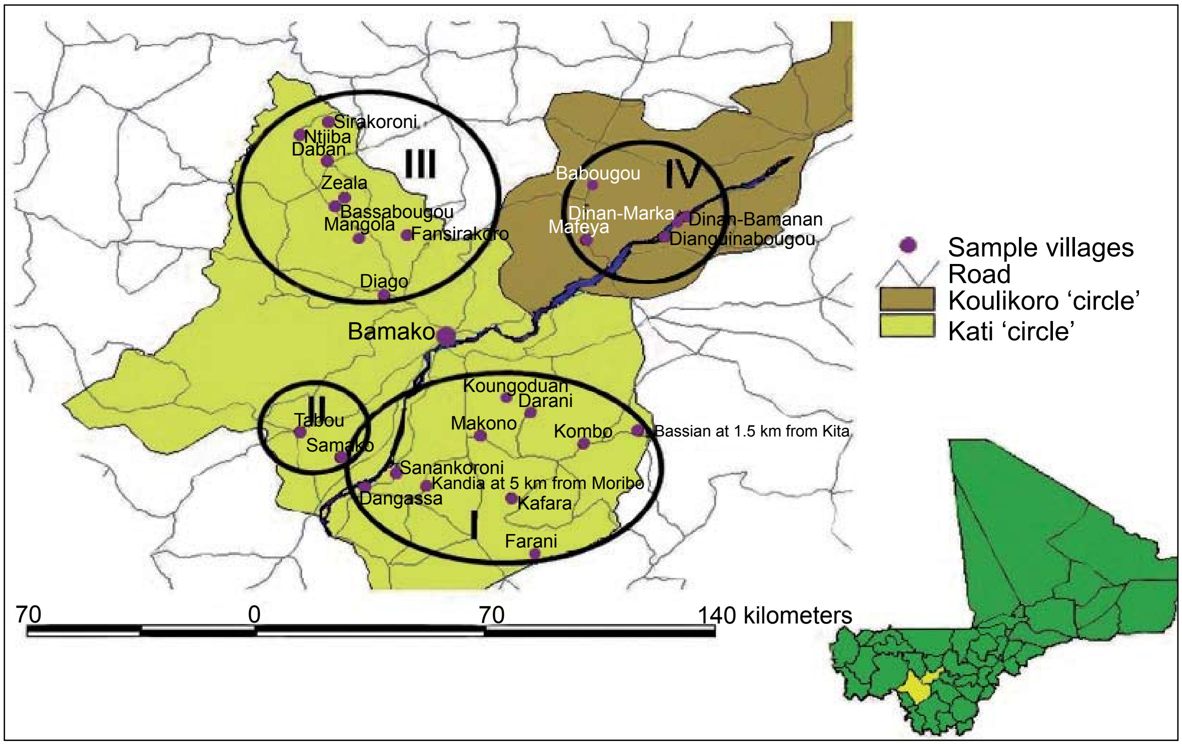

Figure 1. Sampled villages in the OHVN region of Mali.

Zone II, located west of the Niger river but south of the Mande mountains, has heavy muddy soils, which are less prone to erosion. The area forms a bottom valley (lying between the Mande mountains and the Niger river) with high water tables all year round, allowing for crop diversification into vegetables, fruit trees and rice. Nonagricultural sources of revenue are important here. Land pressure is relatively low. The area has reasonably good road access to Bamako and there are fewer NGOs active here compared to Zone I.

Zone III is the area in the circle of Kati, north of the Mande mountains. It is characterized by sandy soils which are less prone to erosion than Zone I. Cereals and cotton are the major rainfed crops grown. Cereals are widely traded. The quality of the physical infrastructure is poor in this zone, which is further characterized by very little NGO intervention.

Zone IV, located in the circle of Koulikoro, is a flat area with sandy to muddy soils less prone to erosion. People rely on rainfed subsistence farming and fishing in villages bordering the river. Land pressure is low and access to Bamako has just recently improved. Extension support from both NGOs and OHVN is relatively weak[1].

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[1] Personal communication, Malick Tessougou, June 21 and July 10, 2006.

3. The NRM Program of the Office de la Haute Vallée du Niger

The Natural Resource Management program began in the late 1980s but significantly expanded only in the early 1990s when donor support increased. Its broad goal is to train communities in NRM and crop production techniques so that they will realize increased levels of food security and income while ensuring continued access to adequate supplies of water, wood and pasture for animals. In a dynamic sense, this implies continuous improvement in crop management and renewal of natural resources over time. The program focused on the eastern and southern parts of the OHVN where rainfall exceeds 800 mm year^{-1} and there is a history of cultivating cash crops (primarily cotton). Following the 1994 devaluation of the currency and a rise in cotton prices, the cotton company, Compagnie Malienne pour le Développement des Textiles (CMDT) removed restrictions on the amount of inputs an individual farmer could obtain on credit. This led to a rapid expansion in cotton cultivation from the oldest part of the cotton zone to the southeast of the OHVN zone. While the cultivated area increased 25% annually during 1994-97 and production by 21% per year, yields declined by 3.1% in the OHVN zone (Kelly 2003).

As yields declined in the older production zones, CMDT actively began promoting cotton in the OHVN, even in areas where the crop had not been considered profitable. Between 1993/94 and 1998/99, the OHVN cotton area grew from 8624 ha to 35,816 ha, and production rose from 10,684 tons to 33,740 tons. Aggregate yields, however, followed the same pattern as in the CMDT zone, declining from 1239 kg ha^{-1} to 942 kg ha^{-1} (OHVN statistics). This trend cannot only be explained by rainfall. Conventional wisdom supports the view that the decline was due to expansion into marginal lands and low use of fertilizers and pesticides. The link between cotton and NRM practice is important since the underlying tenet of the OHVN program is the need for a strong economic incentive if NRM techniques are to be adopted by farmers. Thus far, that economic incentive has been the opportunity to increase household income through cotton production on improved land. This focus on cotton producers is unique to the OHVN/NRM program as many programs target semi-subsistence farmers considered too poor to purchase improved inputs such as fertilizers or pesticides.

The NRM program used participatory approaches in technology testing and delivery. First came field visits aimed at helping communities recognize the environmental problems they were confronting, understand what was causing them, admit that there was a link between their current agricultural practices and the environmental problems and then develop action plans to deal with them. After the initial visits, the NRM program only intervened in communities that were openly receptive to making changes and willing to invest human and/or financial resources. In some villages, this meant a delayed start because communities needed to deal with basic training and organizational issues first (eg, forming a village association if it did not exist, association members obtaining literacy training so that records could be kept and credit applications prepared, etc.).

Assistance with literacy and numeracy training was provided by the national literacy training program in collaboration with OHVN and assistance with organizing village associations came largely from the Cooperative League of the USA (CLUSA) project (funded by USAID as part of its overall assistance package to the OHVN). There is also a strong link between the NRM program and the Département de Recherche sur les Systémes de Production at the Institut d'Economie Rurale (IER) where research has been conducted to identify and test both NRM and seed/fertilizer technologies.

Once a village (or group of villages) is selected to participate in the NRM program, OHVN agents train a technical team composed of approximately 5-10 villagers (selected by their peers) who have completed literacy training programs and are willing to devote one day per week to learning NRM techniques, training others in the village, and organizing community-level NRM activities. The team members (mostly young farmers in societies where leadership is traditionally held by the elders) receive no salary or special benefits from OHVN but most are remunerated (usually in kind rather than in cash) by their communities. After the training, OHVN extension agents continue to provide support to the team as it helps individual farmers and community groups implement their programs. The objective is to promote village-run extension services. More than 20 villages attained this status in 2001 (Kelly 2003).

4. Analytical Framework

Assessing the impacts or uptake of integrated natural resource management (INRM) poses a challenge to scientists. The complexity of INRM interventions requires a more holistic approach to uptake or impact assessment, beyond the plot and farm levels and beyond traditional analyses of economic returns. The impact or uptake assessment (IA/UA) methodology for INRM should help clarify how an intervention affects a society's economic, financial, natural, social, human, physical and other resources. The sustainable livelihood framework described by Scoones (1998) has scope for broad application to IA/UA methods including INRM. Scoones (1998) defines sustainable rural livelihoods as the "…capabilities, assets (including both material and social resources) and activities required for a means of living." This definition can be divided into two subcomponents that reflect the themes of INRM: the first focuses on well-being or livelihoods and includes aspects of employment, income and poverty reduction while the second is the sustainability dimension, which includes the resilience of livelihoods and the natural resource base on which they depend (Gottret and White 2001).

The IA/UA framework is based on the framework of sustainable rural livelihoods (Fig. 2). This framework comprises four components that reflect the state of development (including the context), the process of development (livelihood strategies), institutions and organizations, and R&D interventions. An initial assessment or baseline study describes the current state of livelihood resources or the capital base from which different production processes are derived for each reference site. This capital base has five dimensions:

- Economic/financial capital: the capital assets (cash, credit/debt, and savings) that are essential for the pursuit of any livelihood strategy.
- Physical capital: household assets and farm infrastructure, including production equipment technologies and plantations.
- Natural capital: the stock of natural resources (soil, forest, water, air, genetic resources, etc.) and environment services (hydrological cycle, carbon sequestration, etc.) from which both resource flows and useful resources for livelihood are derived.
- Human capital: the capacities, skills, knowledge, ability to work, good health and physical capability important for the successful pursuit of livelihood strategies. Human capital can be developed consciously through formal education and training and unconsciously through experience.
- Social capital: the social resources (networks, social relations, affiliations, associations, norms, trust and disposition to work for the common good) which people draw upon when pursuing different livelihood strategies requiring coordinated and collective action.

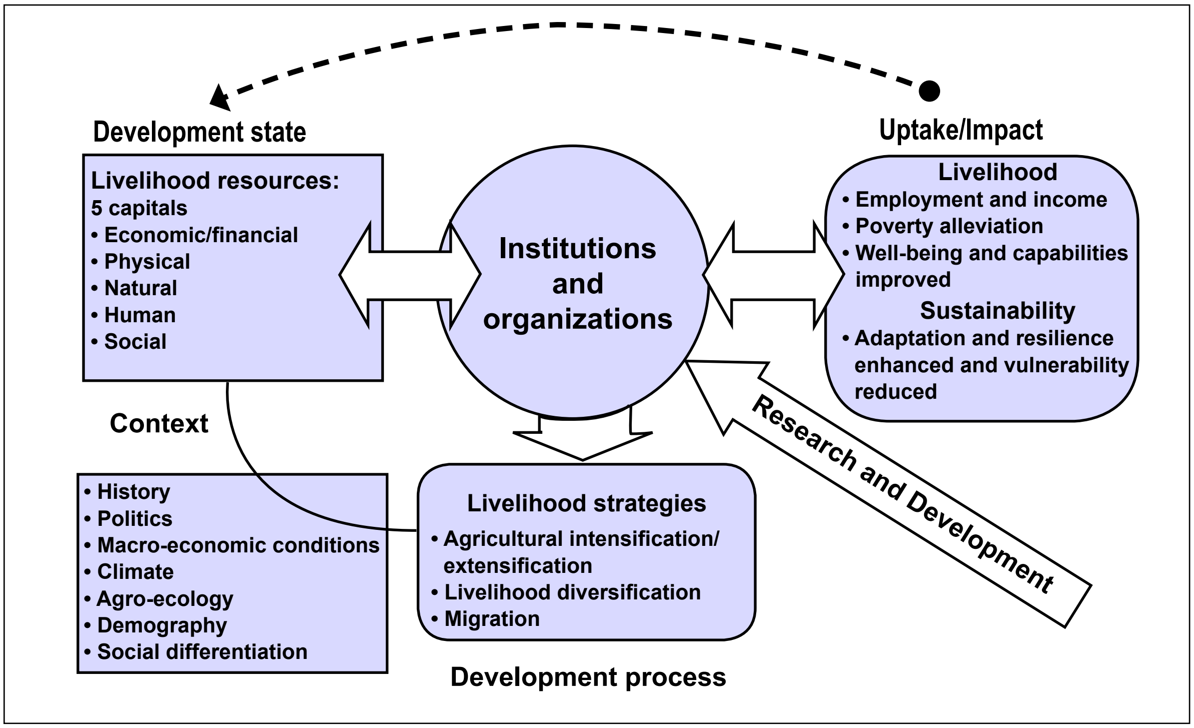

Figure 2. The analytical framework for integrated natural resource management impact assessment on sustainable rural livelihoods (adapted from Scoones 1998).

This baseline also provides a description and contextual analysis of conditions, trends, and policy setting in the community. These components include the exogenous characteristics (structural variables) of a site such as its history, politics, macroeconomic conditions, terms of trade, climate, agroecological conditions, demography and social differentiation.

Households and communities have three broad clusters of livelihood strategies: (1) agricultural intensification/extensification; (2) livelihood diversification within agricultural activities and nonfarm activities; and (3) migration. Livelihood strategies are part of the development processes that enable individuals, households, and communities to reach a modified development state and move from an initial development state towards a subsequent one. If people change their livelihood strategies, then their livelihood outcomes will also change.

Institutions and organizations are at the center, as befits their role in binding the elements of the framework. According to Scoones (1998), understanding institutional processes is a prerequisite to identifying restrictions/barriers and opportunities with regard to sustainable rural livelihoods. Since formal and informal institutions mediate access to livelihood resources, an understanding of institutions and organizations is critical.

For INRM research interventions to have an impact on rural livelihoods, it is not enough to merely produce research outputs (the “what”) that permit a better understanding of system dynamics and processes of a variety of sites (the “where”). It is also essential to identify “who” is going to implement and adopt changes, and “how” to best improve livelihoods. Organizations are the vehicles of change, and are thus the target for R&D interventions and the collective action platform for planning, implementing, and evaluating them. Institutions provide the rules and norms by which individuals and their organizations operate and therefore provide structures that can either hinder or foster development processes. Adopting a sustainable livelihoods approach forces the R&D process to recognize the potentially "… enormous level of organizational and/or institutional failures that exists and (therefore affects) the impact of agricultural research" (Gottret and White 2001).

5. Methodology and Sampling Frame

Following a participatory rural appraisal (PRA) conducted in 2000 (Kelly 2003), a structured survey was carried out at the village, household and plot levels in 2001/02. Villages were purposely selected for the survey on the basis of OHVN agents' perception of the levels of uptake of S&WC technologies (Annexure1). About 20% of the villages were assumed to have high uptake, 30% medium uptake and 50% low uptake. With restrictions posed by survey costs and objectives, a total of 26 villages were selected (5 with high uptake, 8 with medium uptake and 13 with low uptake of S&WC technologies). Road accessibility, population density, agroecological zone, market access and institutional make-up were used to select villages. In each village, an average of 20 households were randomly selected using the list of households provided by the village chief or the list developed by enumerators at the village level during survey implementation. A total of 531 households were interviewed.

Data were collected on human, physical, social, financial and natural assets at the village and household levels. Data were also collected on the vulnerability context including climate, agroecology and demography and the transforming structures such as the market and institutional environment. The village questionnaire sought information on socio-demographic profile and infrastructure, institutional make-up and market infrastructure, endowment of natural resources, drivers of village economies, conflicts and their resolution and technologies disseminated by rural development projects. The household questionnaire included 10 modules: the socio-demographic profile of households, land assets, agricultural equipment used or rented, farmers' perception of productivity gains from technologies used, major information sources on technologies, crop, livestock and off-farm transactions, wealth indicators and household perception of changes in livelihood outcomes including overall well-being, food security and asset accumulation. At the plot level, information on plot characteristics, use of inputs such as fertilizers, improved varieties, soil and water conservation technologies, and perceptions on plot fertility and production were collected.

In 2006, out of the 26 villages selected, 7 were revisited for a focus group interview. The villages[2] were chosen to represent the spatial variation in the sample, as well as uptake levels. Informal group discussions were conducted with farmers to ascertain the levels of uptake perceived by them, which were positively correlated with observed uptake levels, except in the case of two villages, Kombo and Farani. As data exploration and checking revealed the presence of nonreliable data from one enumerator, the number of villages validated was reduced to 25 and the number of households to 494. In effect, this had little incidence on the sample because Karadié was considered a low uptake village among the 15 villages selected.

Cluster analysis was carried out to organize the data into meaningful structures. Descriptive statistics, one-way ANOVA, and measures of association (chi square) were used to characterize

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[2] The seven villages were: Kombo and Farani in the southeast with perceived high uptake of S&WC technologies; Samako (southwest) and Kafara (southeast) with medium uptake; and Daban (northwest), Karadié and Dinan Marka (northeast) with low uptake.

the data and assess differences in the clusters and between users and nonusers of NRM technologies. GIS tools were used to produce informative maps based on drivers of uptake of technologies. At the multivariate level, logit and poisson regression were used to identify factors explaining uptake of at least one S&WC technology. Tobit and median regressions were used to identify the determinants of inorganic and organic fertilizer use and ordinary and median regressions were used to assess the determinants of crop productivity.

6. Results and Discussion

This section presents the results of the cluster analysis. Based on clusters, descriptive statistics on household and plot level data are presented. Household data include the socio-demographic profile, durable assets, social capital and sources of cash income. Likewise, descriptive statistics on production systems, cropping patterns and input use are presented at the plot level. The last subsection presents the drivers of uptake of at least one soil and water conservation technology, determinants of input use and crop productivity.

6.1 Cluster Analysis

A general question facing researchers in many areas of inquiry is how to organize observed data into meaningful structures, ie, to develop taxonomies. Cluster analysis is an exploratory data analysis tool which aims at sorting different objects into groups in a way that the degree of association between two objects is maximum if they belong to the same group and minimal otherwise. Given the above, cluster analysis can be used to discover structures in data without providing an explanation/interpretation. In other words, cluster analysis simply discovers structures in data without explaining why they exist. There are different types of clusters such as tree clustering, the two-way joining, K-means clustering and Expected Maximization clustering. In this case, the method used was the K-median cluster.

Five variables were used to form clusters at the village level: the number of institutions, the agroecological zone, road access, population density, and market access. The number of institutions is the aggregate number of farmers' associations, development projects and nongovernmental organizations (NGOs). The agroecological zone (AEZ) is a discrete variable (0,1), where villages with less than 800 mm rainfall are assumed to be 0 and those with more than 800 mm are affected 1. Road access is also a discrete variable (0,1), where villages that are not accessible at any time are affected 0 and those with better access at any time affected 1. Population density[3] is another discrete variable gleaned from global positioning systems (GPS) of villages with regard to national population densities. Finally, market access was used as a discrete variable where villages with markets were affected 1 and those without markets 0. These variables were selected because they are well-documented as major drivers of uptake of NRM technologies. Table 1 presents descriptive statistics of the variables used in the cluster analysis. About half the villages are accessible by road during all seasons, half are located in environments with less than 800 mm rainfall and only about a third have good access to markets. On an average, the population density in these villages ranges between 12 persons km^{-2} and 35 persons km^{-2}. On an average, there are about two institutions per village.

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[3] Population density: 0 = less than 12 persons km^{-2}; 1 = 12-21 persons km^{-2}; 2 = 21-35 persons km^{-2}; 3 = 35-62 persons km^{-2}; and 4 = 62-496 persons km^{-2}.

Table 1. Descriptive statistics of variables used in the cluster analysis.

Variable	Number	Mean	Standard deviation	Minimum	Maximum
Road access	24	.50	.51	0	1
Population density	24	1.33	1.05	0	4
Agroecological zone	24	.50	.51	0	1
Number of institutions	24	2.38	1.71	0	5
Market access	24	.33	.48	0	1

Source: OHVN Survey 2001/02.

A K-median clustering analysis was done. The data were nominally scaled and an appropriate selected similarity/dissimilarity measure was the matching type. Given the limited data set (24 observations), a prior maximum of 5 clusters were assumed and a partitioning cluster was performed on 2 to 5 clusters. The 2-group solution is best from a clustering standpoint. Table 2 presents the summary statistics of the Kmed2abs. In effect, villages in Group 1 are better endowed: they are located in higher rainfall zones, and have institutions, better road access, higher population density and greater access to markets than Group 2. More than 90% of the villages in group 1 are located south of the OHVN zone.

The 2-group case is more distinct compared with the 3-group, 4-group and 5-group cases, and in effect, the Calinski/Harabasz Pseudo-F stopping rule is the largest for it. The Calinski/Harabasz Pseudo-F values for 2 to 5 clusters are as follows: for 2 clusters Pseudo-F = 28.27; for 3 clusters 19.23; for 4 clusters 14.22; and for 5 clusters 15.43. The first cluster includes 15 villages and the other 9 villages.

To check whether a hierarchical cluster might produce different results, an average linkage cluster analysis was used with the Euclidian distance as a measure of similarity. A cluster dendogram was produced. To check whether the 2-group solution from this hierarchical cluster analysis compared with the 2-group cluster from the K-median clustering, a cross-tabulation between the 2 cluster groups was done. A perfect match was found in the 2-group case whereas there were mismatches in the case of more than 2 groups (Table 3).

Table 2. Summary statistics of the 2 groups formed by the K-median clustering (Kmed2abs).

Kmed2abs	Statistic	Number of institutions	Agroecological zone	Road access	Population density	Access to market
Group 1	Min	1	0	0	1	0
	Mean	3.4	.8	.6	1.93	.53
	Max	5	1	1	4	1
Group 2	Min	0	0	0	0	0
	Mean	.67	0	.33	.33	0
	Max	2	0	1	1	0
Total	Min	0	0	0	0	0
	Mean	2.375	.5	.5	1.33	.33
	Max	5	1	1	4	1

Table 3. Association between the 2- and 4-group clusters formed from K-median clustering (kmed2abs and kmed4abs) compared to average linkage cluster analysis (invgg2 and invgg4)[4].

	invgg2			invgg4			
Kmed2abs	1	2	Kmed4abs	1	2	3	4
1	15	0	1	1	1	2	3
			2	3	2	4	0
2	0	9	3	0	0	0	6
			4	1	0	1	0

The Duda/Hart Statistic stopping rule shows that the 2-group case had the highest stopping rule value of 0.6299. However, the smallest Pseudo T-square of 4.85 was found in the 3-group case. However, this value is also low for the 2-group clusters. Distinct clustering is characterized by larger Calinski/Harabasz pseudo values. As indicated in Table 4, the 2-group solution is the most distinct.

Table 4. Duda/Hart statistic.

Number of pseudo clusters	Duda/Hart	
	Je(2)/Je(1)[5]	Pseudo T-squared
1	0.4599	25.84
2	0.6299	7.64
3	0.5531	4.85
4	0.1071	8.33
5	0.1250	49.00

6.2 Household Economies

This section discusses results from the household data, starting with technology uptake followed by an assessment of differences in household livelihood assets (human, natural and physical, financial and social) based on uptake. Livelihood outcomes proxied by household perceptions of welfare changes; changes in household asset accumulation, food security, health, education and social status based on uptake are also presented.

6.2.1 Uptake of Soil and Water Conservation Technologies

Users of S&WC technologies are defined as those who have applied at least one or more of such technologies in their fields. Conversely, nonusers are those who have not used such technology in any of their fields. Figure 3 depicts the proportion of households using different anti-erosion

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[4] Kmed4abs refers to the 4 groups formed by the K-median clustering and invgg4 refers to the clustering using the average linkage cluster method.

[5] Je(2)/Je(1) is the Duda and Hart stopping rule index produced for hierarchical clustering characterizing distinct clustering. Large Duda-Hart Je(2)/Je(1) values and small Duda-Hart pseudo-T-square values characterize the number of distinct clusters found (Duda and Hart 1973).

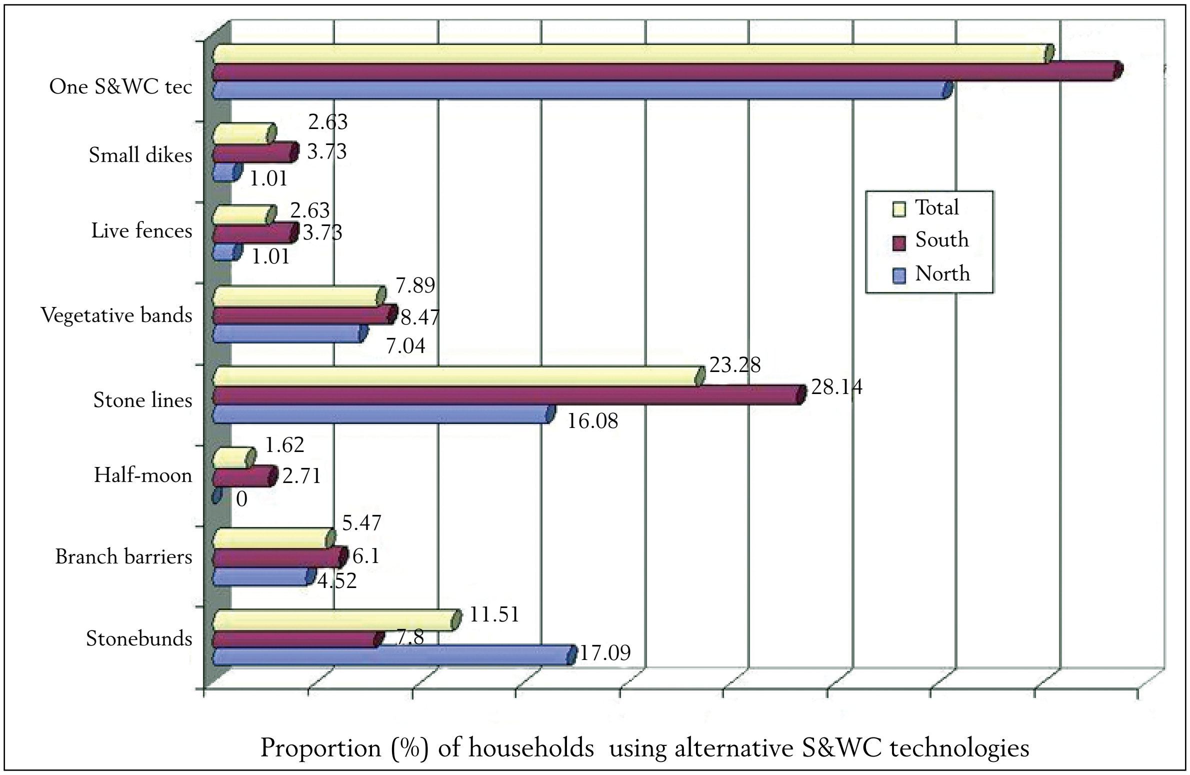

Figure 3. Proportion of farmers using alternative anti-erosion measures in the OHVN zone, 2001-2002.

measures in the OHNV zone during the 2001-2002 agricultural season. About 40% of the households surveyed used at least one S&WC technology. Nearly 26% used only one technology, while over 13% adopted more than one. Just over 60% of the households did not use any S&WC technology.

Uptake levels varied according to the type of technology. Stone lines were used by 23% of the sampled households followed by stone bunds (11.5%). The difference in the use of stone lines and stone bunds is largely explained by the skills required to first establish contour lines and then place the stones on them to build a stone bund. Also, stone bunds may require more stones and labor than stone lines. Vegetative bands were used by 8% of the households. Small dikes were used by over 2% and half-moons by less than 2%. Small dikes are mainly used for rice production, which is not possible in all villages. Half-moons are more suitable for marginal rainfall areas, in which category most of the OHVN zone does not fall; hence their limited use in harvesting rainwater in the zone under study. Uptake may well be much higher in other drier locations within Mali. The proportion of farmers adopting at least one S&WC technology was higher in villages located in the southern part of the OHVN zone than the northern (Fig. 4). This is consistent with the area of focus of the NRM program.

Table 5 shows the number of S&WC technologies used by the surveyed households, as well as the number of years they had been in use as of 2001-2002. Stone bunds, stone lines, living hedges and small dikes had been used for an average of more than 6 years, whereas vegetative bands, branch barriers and half-moons were relatively recent. It is estimated that households placed about 289 m of small dikes, followed by 286 m of stone bunds, 200 m of stone lines and 181 m of vegetative bands. Fewer households used branch barriers, half-moons and live fences, and had less experience in using them. Among users, households placed on an average 73 m of branch barriers, 25 half-moons and 218 sq meters of live fences.

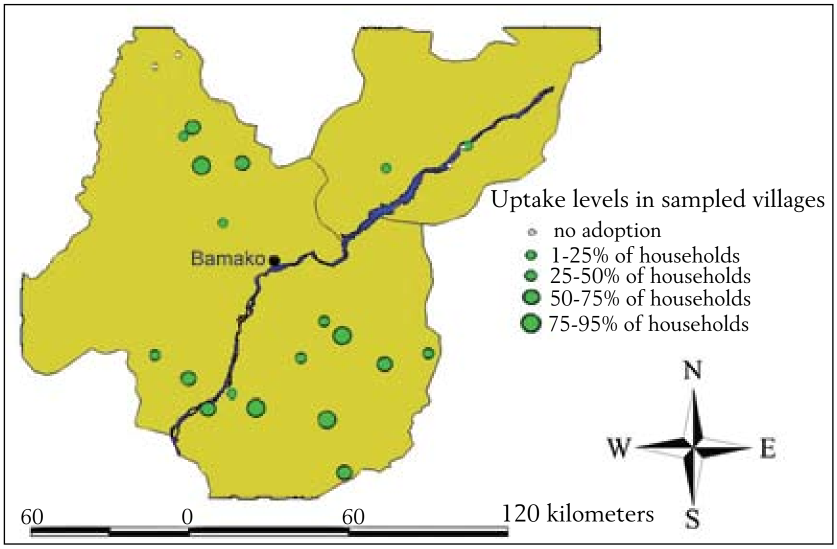

Figure 4. Percentage of farmers adopting at least one S&WC technology in the surveyed villages.

Table 5. Intensity (no.) and duration (years) of uptake of alternative soil and water conservation technologies among households.

Characteristic		Quantity			Number of years of use		
		Group 1	Group 2	Subtotal	Group 1	Group 2	Subtotal
Stone bunds (m)	Number	34	22	56	34	22	56
	Mean	306	256	286	6.76	5.64	6.32
	Standard deviation	591	478	545	3.52	3.19	3.41
Branch barriers (m)	Number	9	17	26	9	17	26
	Mean	132	42	73[b]	3.56	4.00	3.85
	Standard deviation	163	56	111	2.79	2.94	2.84
Half-moons (no.)	Number	0	7	7	0	7	7
	Mean	0	25.43	25.43	0	3.14	3.14
	Standard deviation	0	20.85	20.85	0	1.35	1.35
Stone lines (m)	Number	32	82	114	32	82	114
	Mean	221	190	199	6.72	6.11	6.28
	Standard deviation	417	516	488	3.28	5.52	4.99
Vegetative bands (m)	Number	14	24	38	14	24	38
	Mean	160	194	181	4.5	4.29	4.37
	Standard deviation	191	248	227	2.07	2.77	2.51
Live fences (sq m)	Number	9	23	32	9	23	32
	Mean	235	211	218	5.11	6.00	5.75
	Standard deviation	212	312	284	2.80	3.30	3.15
Small dikes (m)	Number	2	10	12	2	10	12
	Mean	51	337	289	4	11.7	10.5
	Standard deviation	69	429	404	4.24	17.88	16.5

b = significant at 5%.
Source: OHVN survey, 2002.

Spatially, the use of soil and water technologies is not evenly distributed. Uptake is limited in the most isolated northern villages of Sirakoroni, Ntjiba and Daban. In general, stone lines, stone bunds and to a limited extend branch barriers are most commonly used in the low-uptake villages. Uptake of vegetative bands is concentrated in the southeastern corner of the zone and half-moons are exclusively used in three villages in this area. A decrease in the diversity and level of uptake was observed as one moved north across the Niger river.

6.2.2 Human Assets

Table 6 presents the socio-demographic and economic profile of the selected households. On an average, heads of households were relatively older (55 years) with no significant differences between the groups. Similarly within groups, there were no significant differences between users and nonusers of S&WC technologies. Agriculture was the main occupation for 95% of the heads of households, reflecting its importance in rural livelihoods in the OHVN zone, with no differences between groups and between users and nonusers. Similarly, in terms of years of experience in agriculture, there were no differences between the two groups.

However, Group 2 had larger mean household size than Group 1, ie, 20 against 17 respectively. This may be explained by the fact that Group 2 is located in the better-endowed areas where large families are better able to meet their consumption and investment needs. Similarly, within the two groups, there were significant differences in household size between users and nonusers, the former having more family members than the latter. The same pattern was found with respect to total work force. There were more adult equivalents in households in the better-endowed areas. Within the two groups, on average, the number of adult equivalents was significantly higher for users than nonusers. Users have adopted labor-demanding technologies because they are endowed with a larger work force than nonusers. Though migration is known to be important in the zone, it was limited to just over one person per household. However, there were marked differences between the two groups. There were more migrants in the better-endowed areas than in the less-endowed areas. In effect, the better road infrastructure in the better-endowed areas served to reduce migration transaction costs and presented greater options to generate capital for migration, enabling more members of households to migrate to Bamako and neighboring countries. While there were no significant differences between users and nonusers of S&WC technologies within Group 1, significant differences were detected between users and nonusers in Group 2.

Table 7 presents the distribution of households by ethnic group and levels of education. The Bambara ethnic group is the most dominant followed by the Malinke, who are both important technology users. The Bozo (traditional fishermen) and Peulh (traditional herders) were often nonusers of S&WC technologies due to the nature of their main occupations. With regard to education, significant differences were observed between the two groups, with more nonliteracy observed in the well-endowed area, contrary to expectations of finding more educated households where higher education infrastructure exists. It was observed that within Group 2, on an average, more members in the user groups had been educated up to the primary and secondary levels compared to nonusers. A similar trend was observed in the case of koranic, literacy and numeracy levels. This may signal the receptivity of users to technologies, compared to nonusers.

Table 6. Socio-demographic profile of households in selected sites.

		Group 1			Group 2			
		Nonusers	Users	Subtotal	Nonusers	Users	Subtotal	Total
Characteristic		(129)	(70)	(199)	(168)	(127)	(295)	(494)
Age of household head	Mean	55.16	55.56	55.3	54.36	55.39	54.80	55.00
	Standard deviation	14.39	15.36	14.71	20.04	23.32	21.50	19.03
Agriculture as main occupation of household head (% total)		97.67	92.86	95.98	94.01	92.13	93.20	
Years of experience of household head in agriculture	Mean	37.47	38.38	37.79	34.85	41.58	37.81	37.80
	Standard deviation	19.73	15.96	18.45	28.32	14.14	23.52	21.60
Household size	Mean	15.62[b]	18.8	16.74	17.08[a]	24.19	20.15[b]	18.78[b]
	Standard deviation	10.83	09.76	10.55	11.54	15.83	13.99	12.81
Total work force	Mean	8.54	8.81	8.64	8.12[a]	10.88	9.31[b]	9.04[b]
	Standard deviation	6.60	4.98	6.07	6.04	6.99	6.61	6.40
Dependency ratio	Mean	0.95[a]	1.23	1.05	1.22	1.32	1.27	1.18[b]
	Standard deviation	0.57	0.55	0.58	0.80	0.70	0.76	0.70
Temporary migrants (no.)	Mean	0.73	0.79	0.75	1.11	1.23	1.16	0.95
	Standard deviation	1.27	1.28	1.27	1.60	1.56	1.58	1.08
Immigrants (no.)	Mean	0.31	0.26	0.29	1.01	1.88	1.39	1.38[b]
	Standard deviation	0.93	1.03	0.96	2.62	3.87	3.25 [b]	2.64
Handicapped (no.)	Mean	0.15	0.16	0.15	0.27	0.30	0.29	0.23
	Standard deviation	0.38	0.44	0.40	0.60	0.62	0.61	0.25

a = significant at 1%; and b = significant at 5%.
Source: OHVN survey, 2002.

Table 7. The distribution of households by ethnic group in the selected sites and the level of education of the household head.

		Group 1			Group 2			
		Nonusers	Users	Subtotal	Nonusers	Users	Subtotal	Total
		(129)	(70)	(199)	(168)	(127)	(295)	(494)
Ethnic group of household members (no.)								
Bambara	Mean	12.26[b]	18.5	14.46	12.23	12.85	12.5	13.29
	Standard deviation	11.63	10.04	11.47	12.58	15.31	13.80	12.93
Malinke	Mean	0	0	0	4.32	8.38	6.07[b]	3.62[b]
	Standard deviation	0	0	0	9.55	15.82	12.78	10.30
Sarakole	Mean	1.24	0	0.80	0.17	1.95	0.94	0.89
	Standard deviation	4.28	0	3.48	1.22	6.78	4.63	4.20
Peulh	Mean	0.37	0.04	0.26	0.31	1	0.61	0.46
	Standard deviation	2.81	0.20	2.27	1.78	6.54	4.51	1.77
Bozo	Mean	0.37	0.04	0.26	0.31	1	0.61	0.46
	Standard deviation	2.81	0.20	2.27	1.78	6.54	4.51	1.77
Education of household head (no.)								
Nonliterate	Mean	6.26[b]	11.51	8.11	8.42	10.04	9.12	8.71[a]
	Standard deviation	8.40	8.01	8.63	9.44	10.64	9.99	9.47
Primary	Mean	1.75	1.84	1.78	2.35	3.80	2.98	2.50[b]
	Standard deviation	1.94	2.31	2.07	2.69[b]	4.05	3.41	3.00
Secondary	Mean	0.05[b]	0.37	0.17	0.14[b]	0.32	0.22	0.20[b]
	Standard deviation	0.23	1.17	0.73	0.41	0.90	0.67	0.70
Koranic literacy	Mean	0.53	0.34	0.47	0.75	2.10	1.33[b]	0.98[b]
	Standard deviation	1.25	0.61	1.07	2.16	6.60	4.67	3.69
Numeracy/ literacy	Mean	0.24[b]	1.34	0.63	0.97[b]	1.48	1.19	0.96[b]
	Standard deviation	0.54	1.41	1.08	1.27	1.98	1.64	1.46

a=significant at 1%; and b= significant at 5%.
Source: OHVN survey, 2002.

6.2.3 Natural and Physical Assets

Table 8 presents the land and livestock assets owned by households. The average area owned by households in Group 2 was estimated to be 22 ha, not significantly higher than the 12.59 ha owned by Group 1. However, the area cultivated by households in Group 2 was estimated to be 7.54 ha, significantly higher than the 5.89 ha cultivated by households in Group 1. Within the two groups, household users of S&WC technologies cultivated more land than nonusers. For

Table 8. Land and livestock assets owned by the households.

		Group 1			Group 2			
		Nonusers	Users	Subtotal	Nonusers	Users	Subtotal	Total
Characteristic		(129)	(70)	(199)	(168)	(127)	(295)	(494)
Land assets								
Area owned (ha)	Mean	11.05	15.42	12.59	21.03	23.36	22.04	18.22
	Standard deviation	21.90	17.06	20.39	65.70	50.02	59.45	47.89
Area cultivated (ha)	Mean	5.38^{b}	6.81	5.89	6.00^{b}	9.57	7.54	6.9^{a}
	Standard deviation	3.51	3.94	3.72	5.40	6.19	6.02	5.27
Area in fallow (ha)	Mean	2.96^{b}	6.09	4.06	5.68	6.04	5.85	5.13
	Standard deviation	6.80	12.46	9.29	13.89	10.10	12.40	11.27
Number of collective plots	Mean	1.90^{b}	2.37	2.07	2.44	3.45	2.88	2.6
	Standard deviation	1.62	1.34	1.54	1.29	2.65	2.05	1.90
Livestock ownership								
Cattle (mature heads)	Mean	3.34^{c}	5.69	4.17	3.05	6.69	4.64	4.44
	Standard deviation	6.64	11.03	8.49	6.54	13.64	10.38	9.65
Sheep and goats	Mean	3.38^{b}	6.00	4 .30	4.61	8.93	6.46	5.60
	Standard deviation	5.40	6.87	6.07	7.80	11.93	10.03	8.70
Donkeys	Mean	0.55^{b}	0.93	0.68	0.67	1.13	0.87	0.80^{b}
	Standard deviation	0.95	1.09	1.02	0.96	1 .40	1.19	1.129
Calves	Mean	0.68	1.07	0.82	0.76	2.22	1.39	1.16^{b}
	Standard deviation	2.77	2.45	2.66	2.05	4.98	3.68	3.32
Tropical live units	Mean	3.61^{b}	6.17	4.51	3.79	8.05	5.64	5.18
	Standard deviation	5.81	9.22	7.28	6.30	11.68	9.26	8.53

a = significant at 1%; b = significant at 5%; and c = significant at 10%.
Source: OHVN survey, 2002.

example, in Group 2, users cultivated on an average 9.57 ha against 6.00 ha by nonusers. Similarly in Group 1, users of technology cultivated 6.81 ha against 5.38 ha by nonusers. Similar trends, although not significantly different, were observed for the area kept fallow and the number of collective plots.

With regard to livestock, there were no significant differences between the two groups. However, within the groups, users of S&WC technologies owned significantly more cattle, sheep and goats than nonusers. For example, in Group 1 users owned an average of 6 heads of cattle and 6 small ruminants against 3 and 3 respectively by nonusers. In terms of tropical live units (TLU), users owned an average of 6 TLU[6] against 4 TLU by nonusers. Similarly, there were marked differences within the groups. The same trend was reported in Group 2, where users of S&WC technologies owned twice the number of TLU owned by nonusers. This may partially be explained by the fact that adoption of S&WC technologies improved wealth accumulation in households.

Agricultural equipment. It is hypothesized that ownership of agricultural equipment is key to uptake of agricultural technologies. While there were significant differences between the two groups in the ownership of donkeys, no significant differences were reported in the number of oxen, carts, plows and seeders. Significant differences were observed within the groups between users and nonusers of S&WC technologies. For example, in Group 2 (living in the more endowed area), all the users of S&WC technologies owned at least a donkey and more than 2 oxen. Seventy-five per cent of them owned at least one cart; all owned at least a plow and 52% owned at least a seeder (Table 9).

Table 9. Agricultural equipment owned by households.

		Group 1			Group 2			
Characteristic		Nonusers (129)	Users (70)	Subtotal (199)	Nonusers (168)	Users (127)	Subtotal (295)	Total (494)
Donkeys (no.)	Mean	0.40[c]	0.61	0.47	0.59	1.00	0.77	0.65[a]
	Standard deviation	0.73	0.86	0.78	0.88	1.03	0.97	0.91
Oxen (no.)	Mean	1.57	1.87	1.68	1.41[a]	2.48	1.87	1.79
	Standard deviation	1.88	1.91	1.89	1.75	1.99	1.93	1.91
Phytosanitary treatment equipment	Mean	0.02	0.00	0.015	0.07[a]	0.29	0.17	0.11
	Standard deviation	0.15	0.00	0.12	0.26	0.64	0.48	0.38
Carts (no.)	Mean	0.36[a]	0.64	0.46	0.45[a]	0.75	0.58	0.53
	Standard deviation	0.54	0.72	0.64	0.59	0.64	0.63	0.64
Plows (no.)	Mean	0.71	0.80	0.74	0.66[b]	1.05	0.83	0.79
	Standard deviation	0.69	0.86	0.75	0.69	0.91	0.81	0.79
Seeders (no.)	Mean	0.31[b]	0.49	0.37	0.29[a]	0.52	0.39	0.38
	Standard deviation	0.58	0.65	0.61	0.49	0.64	0.57	0.59

a = significant at 1%; b = significant at 5%; and c = significant at 10%.

Source: OHVN survey, 2002.

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[6] TUL stands for tropical live units.

About 60% of the nonusers in Group 2 owned at least one donkey and one ox. Less than 50% of the nonusers owned a cart, 66% at least a plow and 29% a seeder. A similar trend was reported for users and nonusers in Group 1.

Their poor endowment of equipment and traction power in combination with limited human resources may explain why nonusers have not adopted S&WC technologies (Table 9). The ownership of assets such as oxen and carts can significantly enhance uptake since they are needed to transport stones, for example. Thus, households that do not own carts are less likely to adopt such technologies. Similarly, plows can facilitate building of small dikes.

Durable household assets. There were few differences in the ownership of durable assets between Groups 1 and 2, except the ownership of motorcycles and radios (Table 10). However, there were marked differences within the groups between users and nonusers. Group 2 showed significant differences in the number of bicycles, sewing machines, houses, motorcycles and radios between users and nonusers, while in Group 1, significant differences were observed in the number of beds and radios. However, the differences in the average value of durable assets owned by households were not significant.

Table 10. Durable assets owned by the households in 2002.

Characteristic		Group 1 (n = 199)			Group 2 (n = 295)			Total (n = 494)
		Nonusers	Users	Subtotal	Nonusers	Users	Subtotal	
Number of								
Bicycles	Mean	1.50	1.94	1.66[b]	1.74	2.21	1.94[b]	1.82
	Standard deviation	1.16	1.25	1.21	1.49	1.61	1.55	1.42
Beds	Mean	.21[a]	1.47	.66	.84	1.57	1.15	.93
	Standard deviation	1.09	2.63	1.89	2.73	3.31	3.00	2.58
Sewing machines	Mean	.02	.014	.02	.03	.10	.06[c]	.04
	Standard deviation	.15	.12	.14	.16	.52	.36	.28
Typewriters	Mean	0	0	0	.01	.01	.01	.00
	Standard deviation	0	0	0	.08	.10	.09	.07
Houses	Mean	6.11	7.1	6.46	6.95	8.30	7.51[c]	7.05
	Standard deviation	4.27	4.03	4.20	5.56	7.15	6.29	5.49
Motorcycles	Mean	.15	.23	0.18	.16	.30	.22[b]	.20[a]
	Standard deviation	.36	.49	0.41	.43	.54	.48	.45
Motor pumps	Mean	0	0	0 0	.01	.00	.00	
	Standard deviation	0	0	0 0	.10	.063	.05	

Continued...

Table 10. *Continued...*

		Group 1 (n = 199)			Group 2 (n = 295)			Total (n = 494)
Characteristic		Nonusers	Users	Subtotal	Nonusers	Users	Subtotal	
Millers	Mean	.00	.1	.04	.01	.09	.04	.04
	Standard deviation	7.09	.73	.44	.12	.61	.40	.42
Radios	Mean	.94	1.39	1.10[b]	.03	.11	.06[b]	1.29[b]
	Standard deviation	1.08	1.30	1.18	.18	.32	.24	1.37
Value (in FCFA)								
Bicycles	Mean	58043	89684	69286	76407	83584	79398	7888
	Standard deviation	73823	98882	84712	88676	80561	85297	32914
Beds	Mean	2106	11346	5389[a]	7274	13435	9841	3034
	Standard deviation	13330	21574	17255	28324	54185	41139	37150
Sewing machines	Mean	945	2143	697	9429	4335	890	
	Standard deviation	6228	17928	5041	74796	48491	14913	
Typewriters	Mean	0	0	0	680	2857	1587	379205
	Standard deviation	0	0	0	8248	29277	19898	1691302
Houses	Mean	333459	703352	464894	25029	294286	12220	66551
	Standard deviation	583771	4065416	2463528	58537	500348	596838	199249
Motorcycles	Mean	38000	90400	56619	53367	103643	74315	1113
	Standard deviation	113364	256088	17883	163954	266809	213889	23596
Motor pumps	Mean	0	0	0	0	4762	1984	11389
	Standard deviation	0	0	0	0	48795	31497	99743
Millers	Mean	6299	19642	11040	12074	11085	11662	14285
	Standard deviation	70988	155508	108599	103672	74428	92451	39148
Radios	Mean	8238	15504	10820[b]	17408	16413	16993	12176
	Standard deviation	17167	24717	20413	59258	29084	48921	48722
Television sets	Mean	1771	7528	3817[b]	15070	23806	18710	
	Standard deviation	10513	25189	17379	56189	70311	6247	

a = significant at 1%; b = significant at 5%; and c = significant at 10%.
Source: OHVN survey, 2002.

6.2.4 Financial Assets

Table 11 presents the average amount of cash income generated by households from alternative sources. Overall, there were significant differences in the total cash sales generated by households in Group 2 (426,696 FCFA) compared to those in Group 1 (277,067 FCFA). This may be explained by differences in crop sales and off-farm income. There were no significant differences in the contribution of cotton to total sales. Within the groups, there were significant differences between users and nonusers. The share of cotton in total cash sales was very high for users (86%) compared to nonusers (68%) in Group 2. Users of S&WC technologies generated more cash from crop sales, livestock, and off-farm activities in this group. In Group 1, no significant differences were observed between users and nonusers except in the case of income generated from off-farm activities.

Crops sales accounted for the largest source of cash income (61%), followed by non-farm activities (27%) and livestock (12%). Overall, cotton was the major source of cash income, accounting for about 68% of total crop cash sales. Within groups, there were significant differences between users and nonusers of S&WC technologies based on the proportion of cotton to total crop sales, reflecting the importance of cotton as a source of cash income in the livelihoods of the poor. The highest incomes were generated in the southern part of the OHVN zone (Fig. 5).

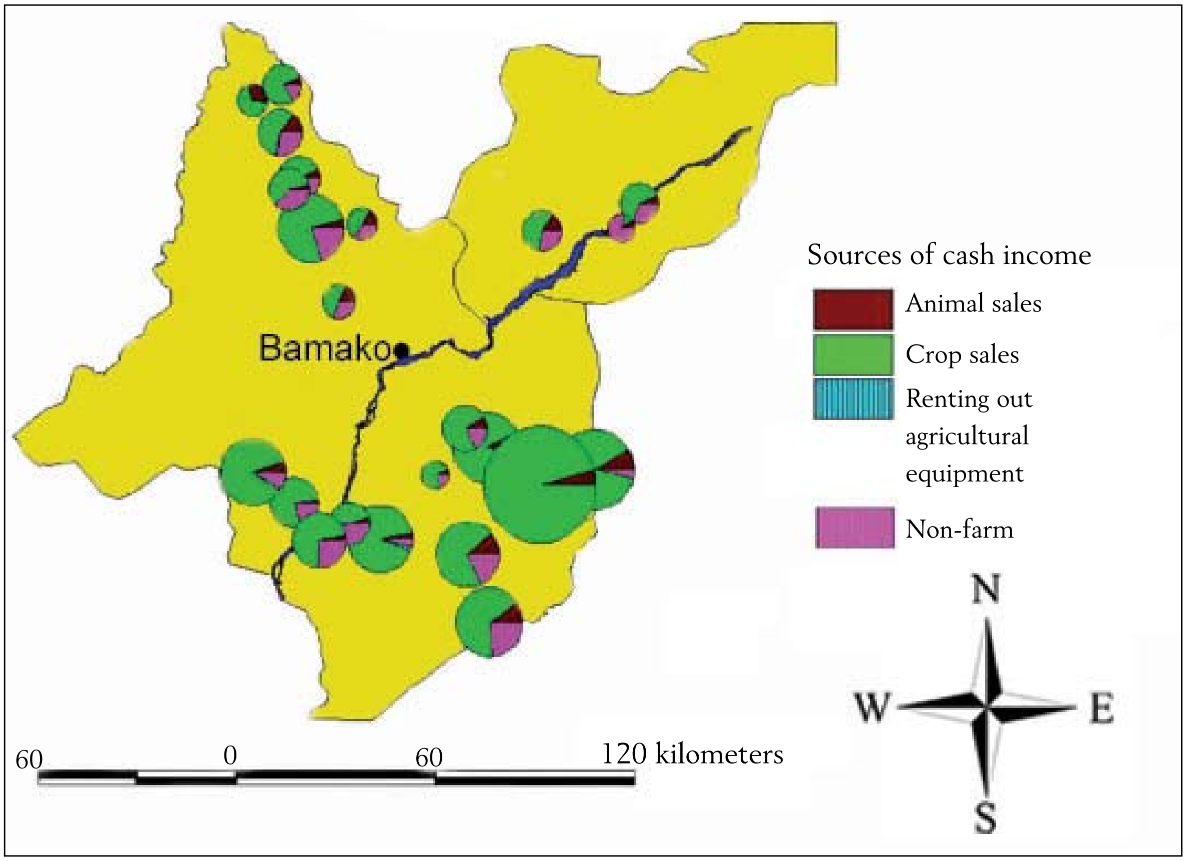

Figure 5. The proportion of cash income from alternative sources in the surveyed villages in Mali.

Table 11. The proportion and levels of cash income generated by households from alternative sources.

		Group 1 (n=199)			Group 2 (n=295)			
Characteristic		Nonusers (129)	Users (70)	Subtotal (199)	Nonusers (168)	Users (127)	Subtotal (295)	Total (494)
Crop sales (FCFA)	Mean	104653	321830	181047	217003[b]	523251	349501	281504[b]
	Standard deviation	227149	350322	294843	395593	607969	520742	450911
Cotton share	Number	60	59	119	103	99	202	321
	Mean	0.67[c]	0.79	0.73	0.68[a]	0.86	0.77	0.68
	Standard deviation	0.44	0.33	0.39	0.44	0.29	0.38	0.39
Sorghum share	Mean	0.0	0.0	0.0	0.02	0.01	0.01	0.01
	Standard deviation	0	0.03	0.02	0.10	0.05	0.08	0.07
Groundnut share	Mean.	0.31[a]	0.04	0.17	0.20[b]	0.10	0 .15	0.16
	Standard deviation	0.43	0.14	0.35	0.37	0.26	0.32	.33
Crop sales share	Number	107	67	167	140	117	257	431
	Mean	0.43[c]	0.67	0.52	0.61	0.73	0.66	0.61
	Standard deviation	0.42	0 .33	0.41	0.41	0.36	0.39	0.40
Livestock	Number	129	70	199	168	127	295	494
	Mean	23734	40486	29626	18766[b]	37809	26964	28036
	Standard deviation	68483	74631	70973	58210	98728	78685	75611
Livestock share	Number	107	67	174	140	117	257	431
	Mean	0.22	0.14	0.19	0.08	0.06[b]	0.07	0.12
	Standard deviation	0.36	0.25	0.32	0.21	0.16	0.19	0.26
Non-farm sales	Number	129	70	199	168	127	295	494
	Mean	51260[b]	94282	66393	44945	58745	50886	57132
	Standard deviation	97759	133651	113257	89091	126174	106669	109522
Non-farm share	Number	107	67	174	140	117	257	431
	Mean	0.35[b]	0.18	0.29	0.31[b]	0.21	0.27	0.27[b]
	Standard deviation	0.42	0.23	0.36	0.40	0.34	0.38	0.37
Total sales	Mean	179647[a]	456598	277067	280715[a]	619805	426696	366420[a]
	Standard deviation	272204	412556	353257	424045	638822	552560	487437

a = significant at 1%; b = significant at 5%; and c = significant at 10%.

Source: OHVN survey, 2002.

6.2.5 Social Assets

Agents of OHVN were reported to be the most important source of information for new technologies, followed by farmers and farmer associations (Table 12). Other extension agents, rural radio and agents from development projects were also found to be important sources of information on S&WC technologies. Farmers in Group 2 claimed to receive more information from OHVN agents than farmers in Group 1. This could be explained by the early concentration of OHVN activities south of the Niger river. In general, within groups, users of S&WC technologies were more informed about the new technologies than nonusers. Paradoxically, households from Group 1 were better at using Information and Communication Technology (ICT) than households in Group 2. In fact, this seems to be inconsistent with the fact that households from Group 2 were richer than Group 1 and were more likely to possess instruments of ICT.

6.2.6 Perceived Impacts of S&WC Technologies

For most soil and water conservation technologies, there is a time-lag between their initial implementation and felt impacts or productivity gains. Farmers reported that on an average they had to wait for 3 years to see the effects of stone bunds, stone lines and wood barriers on productivity gains, whereas for technologies such as vegetative bands, living hedges and small dikes, they had to wait only for a year.

All 14 farmers using dikes found the technology had a positive impact on the plot's fertility. Similarly, 89% of those using stone lines or stone bunds perceived positive changes since 1995. The same trend was observed for other technologies. However, 7% of the farmers using living hedges reported that it negatively affected the field's fertility. This may be explained by the fact that living hedges are often planted with *Jatropha curcas*, the roots of which stretch out up to 2 meters to each side of the hedge, thereby constraining the development of other vegetation. The fact that 2% of the farmers observed negative changes in soil fertility due to the adoption of stone lines is more difficult to explain. Except for half-moons, where 73% of the users perceived productivity gains of less than 20%, productivity gains derived from using other technologies were found to range between 20% and 60% for more than 67% of users.

Table 12. The proportion (%) of households obtaining information from alternative sources.

	Group 1			Group 2			
Source of information	Nonusers (129)	Users (70)	Subtotal (199)	Nonusers (168)	Users (127)	Subtotal (295)	Total (494)
Other farmers	31.78	35.71	33.17	29.34	43.31	35.59	34.41
OHVN agent	51.94	94.29	66.83	63.47	89.76	74.58	71.46
Other extension agents	17.05	21.43	18.59	9.58	9.45	9.49	13.16
Radio	17.83	32.86	23.12	10.18	17.32	13.22	17.21
Farmers' association	21.71	34.29	26.13	16.17	19.69	17.63	21.05
Television	11.63	27.14	17.09	2.40	7.87	4.75	9.72
Research institution	2.33	14.29	6.53	1.80	3.94	2.71	4.25
Development project	2.33	21.43	9.05	12.57	19.69	15.59	12.96

Source: OHVN survey, 2002.

Table 13. The proportion (%) of households reporting their perception of welfare changes from 1995 to 2002.

	Group 1			Group 2			
Characteristic	Nonusers (129)	Users (70)	Subtotal (199)	Nonusers (168)	Users (127)	Subtotal (295)	Total (494)
Overall welfare							
Decreased	41.86	4.29	28.64	16.07	7.09	12.24	18.86
Unchanged	23.25	31.43	26.13	37.13	11.81	26.19	26.17
Improved	34.88	64.29	45.23	46.71	81.10	61.56	54.97
Food security							
Decreased	54.26	7.14	37.69	22.02	8.66	16.33	24.95
Unchanged	14.73	15.71	15.08	30.95	17.32	25.17	21.10
Improved	31.01	77.14	47.24	47.02	74.02	58.50	53.96
Asset accumulation							
Decreased	48.48	8.57	34.67	19.64	11.02	15.99	23.53
Unchanged	20.16	14.29	18.09	36.90	17.32	28.57	24.34
Improved	31.01	77.14	47.24	43.45	71.65	55.44	52.13

Source: OHVN Survey, 2002.

6.2.7 Farmers' Perception of Welfare Changes

Livelihood outcomes are reflected in changes in household assets, food security, well-being, reduced vulnerability and more sustainable use of natural resources. A qualitative assessment by farmers of changes in their livelihood outcomes revealed that overall a high proportion of farmers surveyed in the OHVN zone reported accumulation of more assets (52%), greater food security (54%) and positive changes in overall well-being (55%) (Table 13). However, a larger proportion of farmers in Group 2 reported significant changes in their overall welfare than those in Group 1. For example, 62% of households in Group 2 reported significant changes in overall welfare compared to 45% in Group 1. Similarly, about 55% of farmers in Group 2 claimed to have accumulated more assets against about 47% by Group 1.

Likewise, there were marked differences within groups. In both groups, the proportion of users reporting positive changes in their welfare were almost double that of nonusers. However, it may be difficult to attribute this exclusively to uptake of S&WC technologies. In fact, in the South of the OHVN zone, the Government has invested hugely in improving roads, health and education facilities. Also, the zone grows cash crops such as cotton which serve as a source of foreign exchange. However, because households generate more revenues from farm and non-farm activities, they may invest more on education and even health.

6.3 Production Systems, Cropping Patterns and Input Use

6.3.1 Uptake of Technologies at the Plot Level

Overall, out of the 2259 plots, households applied at least one soil and water conservation practice on about 20% of the plots, only one technology on about 16% of the plots, two technologies on about 3% of the plots and three technologies in less than 1% of the plots (Fig. 6).

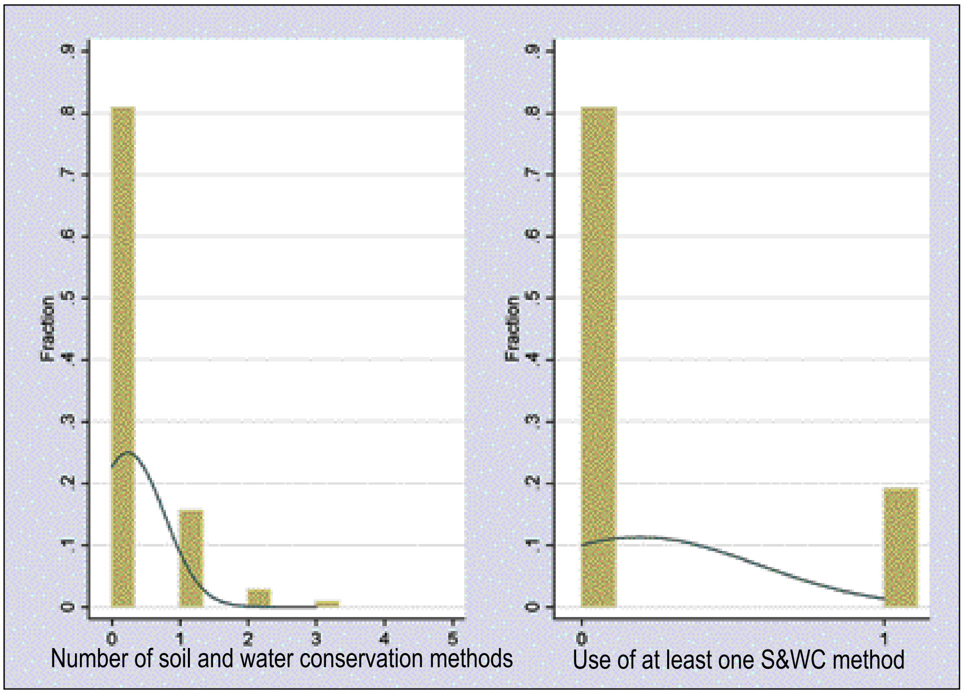

Figure 6. The number of soil and water conservation methods used per plot and the proportion of plots in which at least one soil and water conservation method was used.

A similar uptake pattern was observed at the household level. Stone lines were used in 10% of the plots and stone bunds in about 5%. Between 2 and 3% of all sampled plots had vegetative bands. A similar pattern was observed for branch barriers or living hedges (Table 14).

Inorganic and organic fertilizer use. Table 15 presents the intensity of organic and inorganic fertilizer use. The average use of inorganic fertilizers was estimated at 36 kg/ha with no significant difference between groups. This amount was largely above the national average estimated at 9.5 kg/ha (FAOSTAT 2006). Similar results were recorded for organic fertilizers. Overall, the value of inputs used did not differ significantly between groups. However, there were significant differences between users and nonusers within groups. In Group 2 for example, households using S&WC technologies applied on an average 52 kg/ha of inorganic fertilizers against 35 kg/ha by nonusers. Likewise, in Group 1, users of S&WC technologies applied about 1081 kg/ha of organic fertilizers against 300 kg/ha by nonusers. Users applied on an average nearly double the amount of fertilizers that nonusers did.

Use of inorganic fertilizer was concentrated in two areas in the OHVN zone, the southeastern corner and in some villages just northwest of Bamako (Fig. 7). Northwest of Bamako, fertilizer was also ordered through the OHVN office (because of access to fertilizer on credit), but was for a large part applied to boost cereal production (not just on cotton). In the “cercle” of Koulikoro, fertilizer use was extremely limited. Fertilizer use intensity differed by crop and increased according to its commercial value.

For example, an average household applied 5 kg/ha of inorganic fertilizer on millet, 2 kg/ha on groundnut, 1 kg/ha on cowpea, and about 10 kg/ha on rice fields. Households applied more than the recommended doses on crops like cotton, i.e. 180 kg/ha, and on maize 46 kg/ha which is becoming a cash crop.

Table 14. Intensity and duration of use of alternative soil and water conservation technologies at the plot level.

		Group cluster		
Technology		Group 1	Group 2	Total
Stone bunds	Number	74	44	118
	Quantity (meters)	140.65	127. 77	136
	Standard deviation	195.97	181.0	190
	Number of years of experience	5.84	5.43	6
	Standard deviation years	3.12	2.81	3
Branch barriers	Number	23	29	52
	Quantity (meters)	51.48	24.79	37[b]
	Standard deviation	68.45	44.92	58
	Number of years of experience	3.13	3.34	3
	Standard deviation years	1.77	2.52	2
Half-moons	Number	0	7	7
	Quantity (number)	0	25.43	
	Standard deviation	0	20.85	
	Number of years of experience	0	3.14	3
	Standard deviation years	0	1.34	1
Stone lines	Number	70	152	222
	Quantity (meters)	100.81	102.5	102
	Standard deviation	187.10	299.66	269
	Number of years of experience	6.06	5.89	6
	Standard deviation years	3.53	4.70	4
Vegetative bands	Number	19	39	58
	Quantity	118.21	119.18	119
	Standard deviation	149.89	191.76	178
	Number of years of experience	4.11	3.66	4
	Standard deviation years	2.33	2.33	2
Living hedges	Number	18	33	51
	Quantity (meters)	117.28	147.45	137
	Standard deviation	135.69	234.69	204
Exp. living hedges	Number of years of experience	5.61	6.15	6
	Standard deviation years	2.35	3.12	3

b = significant at 5%.

Source: OHVN survey, 2002.

The use of organic fertilizers is concentrated in the drier part of the OHVN zone, the northwestern part (Fig. 8). There were no significant differences in organic fertilizer use intensities between the two groups. However, within a group users of the NRM technologies applied more organic fertilizers than nonusers (Table 15). In effect, in Group 1, users of the NRM technologies applied 1081 kg/ha against 300 kg/ha by nonusers. A similar trend was recorded in Group 2. This can largely be explained by the fact that users of fertilizers own more livestock than nonusers.

Table 15. Fertilizer use (per ha) among users and nonusers of S&WC technologies.

		Group 1			Group 2			
		Nonusers (672)	Users (170)	Subtotal (842)	Nonusers (1170)	Users (261)	Subtotal (1431)	Total (2259)
Inorganic fertilizers (kg/ha)	Mean	25.23[a]	63.16	32.89	34.68[a]	52.41	37.94	36.06
	Standard deviation	67.66	102.01	77.30	76.05	84.36	77.92	77.71
Organic fertilizers (kg/ha)	Mean	299[a]	1081	457	130.96[a]	715	246	319.88
	Standard deviation	1315	3071	1837	1017	3317	1759.63	
Value of all inputs used (FCFA/ha)	Mean	8356[c]	24856	11688	14951	36174	18860	16186
	Standard deviation	25064	48779	31989	50286	85258	58864	

a = significant at 1%; and c = significant at 10%.
Source: OHVN survey, 2002.

6.3.2 The Production System and Plot Characteristics

Households in the OHVN zone grew a range of crops including cereals such as sorghum, pearl millet, maize and rice, leguminous crops (groundnut and cowpea) and fiber crops such as cotton. These were grown as inter- and sole crops. Sole cropping was practised in about half of the fields and intercropping in the remaining fields. Households could grow up to seven crops per field. As a sole crop, groundnut was planted in about 34% of all monocropped fields followed by sorghum (27%). Cotton, maize and millet were planted as sole crop in 13%, 11% and 10% of the fields, respectively. The major intercroppings were sorghum- and groundnut-based.

The average plot size was estimated to be 1.6 ha and located 1.6 km from the farmer's homestead (Table 16). On an average, a plot was about 16 years old, with plots of users of S&WC technologies being slightly older. This may indicate that the use of technologies prolongs the time a field can be cultivated. According to farmers, 40% of the plots were estimated to be of poor fertility, another 40% of average fertility, and only 20% of good fertility. About 72% of all the sampled plots were located in the flat lowland.

Plots with a pure stand of millet were 3 ha larger than sorghum fields that averaged about 2 ha and cotton fields that averaged 1.6 ha. Maize fields averaged 1 ha, while groundnut fields averaged about 0.8 ha. Fields planted to other crops had an average size ranging between 0.35 and 0.66 ha. The same trend was reported between groups.

There were however differences within groups between users and nonusers of soil and water conservation technologies. In Group 2, for example, users planted on an average 11.3 ha against 9.85 ha by nonusers. The average plot size was estimated to be 2.79 ha for users, almost double that of nonusers (1.45 ha). In Group 2, about 70% of households who used S&WC technologies perceived the fertility of their plots to be at least average against 55% for nonusers. A similar trend was reported for their perception of production levels. With regard to the position of the plot on the toposequence, it was observed that farmers in Group 2 faced more sloping land than farmers in Group 1. This may explain the need for farmers in Group 2 to use more soil and water conservation technologies than farmers in Group 1.

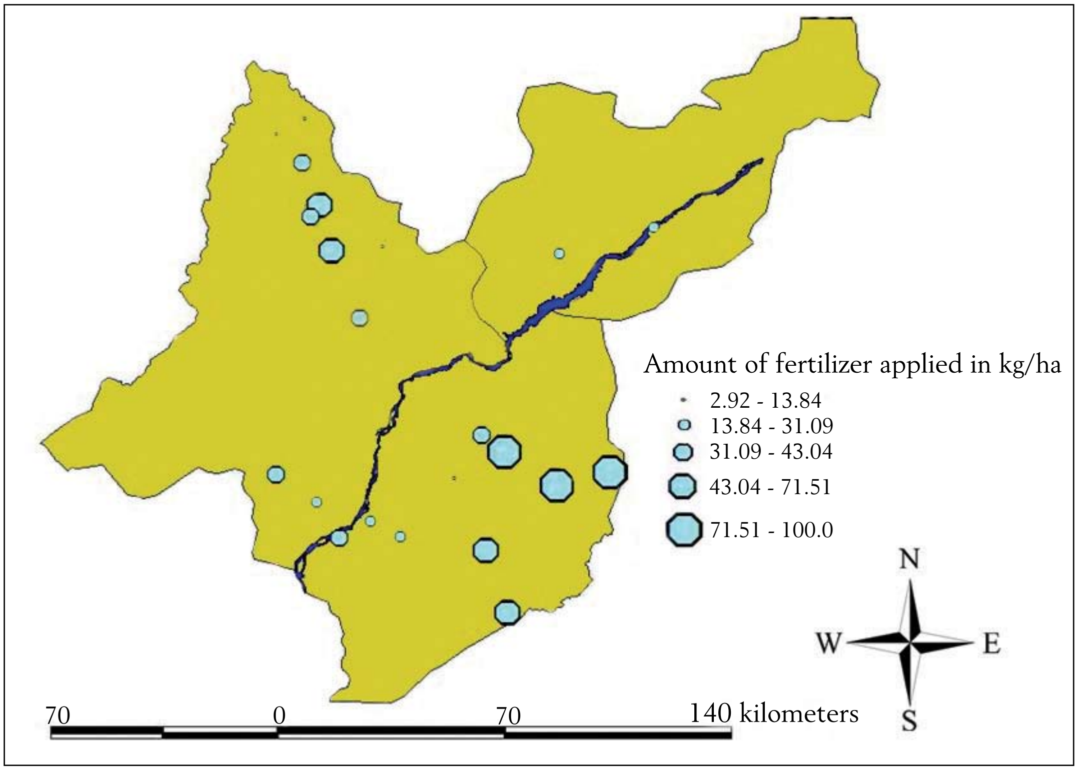

Figure 7. Intensity of inorganic fertilizer use in the surveyed villages.

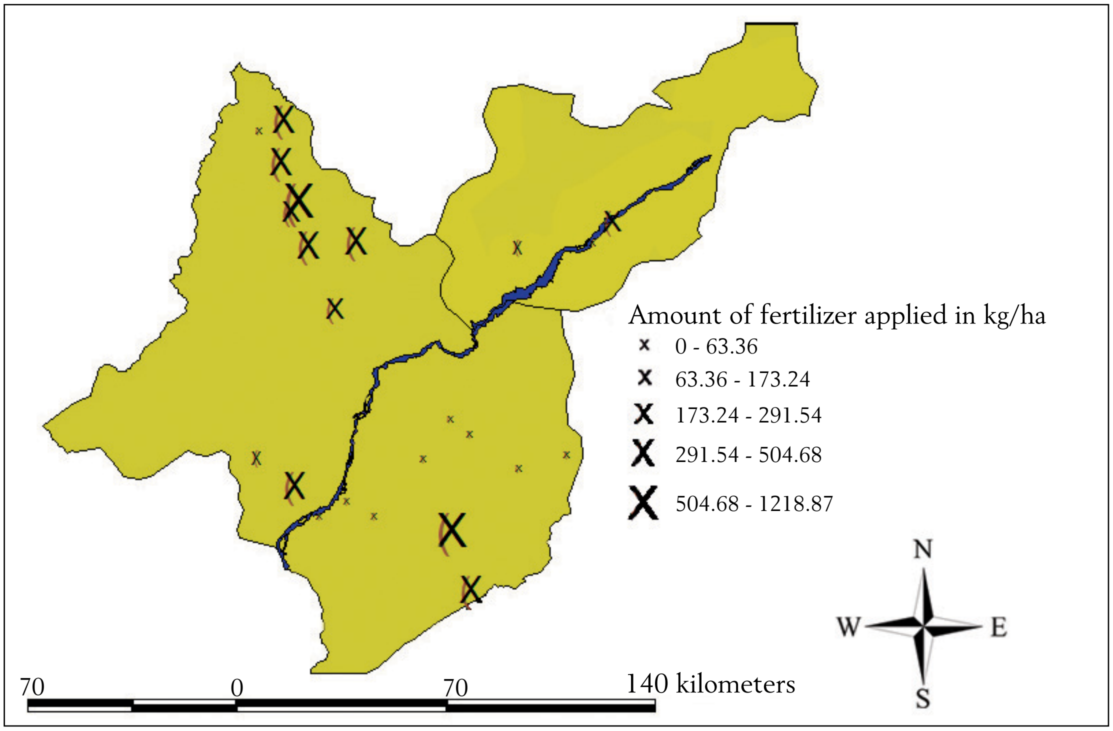

Figure 8. Intensity of organic fertilizer use in the surveyed villages.

Table 16. Major biophysical characteristics of the plots surveyed.

		Clusters						
		Group 1			Group 2			
Characteristic		Nonusers (672)	Users (170)	Subtotal (842)	Nonusers (1170)	Users (261)	Subtotal (1431)	Total (2259)
Area planted (ha)	Mean	7.75	8.04	7.81	9.54[a]	11.28	9.85	9.13
	Standard deviation	4.61	3.99	4.48	7.50	6.57	7.37	6.54
Distance from homestead (km)	Mean	1.57	1.45	1.54	1.56[a]	2.16	1.67	1.62
	Standard deviation	1.43	1.10	1.37	1.89	3.16	2.31	2.02
Age of the plot (years)	Mean	12.65	13.93	12.90	16.86	20.62	17.54	16.87
	Standard deviation	14.17	12.61	13.87	15.91	15.91	15.97	15.42
Plot size (ha)	Mean	1.45[a]	1.86	1.54	1.45[a]	2.79	1.70	1.64
	Standard deviation	1.67	1.65	1.67	1.93	2.48	2.11	1.96
Perception of fertility level (%)	Poor	44.64	30.00	41.69	41.57	28.35	39.13	40
	Average	38.69	40.59	39.07	38.89	44.83	39.97	39
	Good	15.18	22.35	16.63	18.38	24.52	19.50	19
	Very Good	1.49	7.06	2.61	1.20	2.30	1.40	2
Perception of production level (%)	Good	9.67	24.12	12.59	18.29	22.99	19.15	17
	Average	40.77	42.94	41.21	46.15	47.89	46.47	45
	Bad	49.55	32.94	46.20	35.56	29.12	34.38	39
Position on the toposequence (%)	Top	3.27	1.76	2.97	3.42	6.13	3.91	5
	Slope/ramp	4.32	50	13.54	7.35	22.22	10.06	15
	Lowland	75.74	34.71	67.46	42.39	41.00	42.14	
	Top and slope	2.08	2.94	2.26	0.85	5.75	1.75	3
	Slope and lowland	1.04	9.41	2.73	2.65	9.58	3.91	5
	No response	13.54	1.18	11.05	43.25	15.33	38.16	

a = significant at 1%.
Source: OHVN survey, 2002.

Productivity. Table 17 presents the yields of major crops under sole and intercropping systems[7] in the surveyed villages. Under sole cropping system, yields of the major crops were not significantly different between users and nonusers of soil and water conservation technologies, except in the case of sorghum and cotton. In Group 1 for example, sorghum yields averaged 506 kg/ha for nonusers against 596 kg/ha for users and cotton yields were estimated to be 732 kg/ha for nonusers against 896 kg/ha for users. The same trend was recorded for Group 2. In effect, the OHVN zone provides fertilizer on credit that is often used for cotton. Cotton is invariably sown before sorghum on 75% of the sorghum fields, meaning that sorghum benefits from residual fertilizers left from cotton. As for sorghum, despite the differences in yields between users and nonusers, yields were below the national average (2000-2003) estimated to be 836 kg/ha (FAOSTAT 2006).

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[7] Yield under mixed cropping was computed as plot production over the proportion of area occupied by the crop × the plot size.

Table 17. Yields of the major crops which were grown under sole and/or intercropping systems.

		Clusters						
		Group 1			Group 2			
Crop		Nonusers	Users	Subtotal	Nonusers	Users	Subtotal	Total
Sole cropping								
Sorghum	Number	119	40	159	195	62	257	451
	Mean	506	596	529	593	671	612	
	Standard deviation	504	318	465	365	501	402	
Pearl millet	Number	70	16	86	49	18	67	153
	Mean	53	393	117	541	559	546	
	Standard deviation	2446	209	2209	367	389	370	
Groundnut	Number	129	13	142	258	24	282	424
	Mean	950	708	928	704	652	699	
	Standard deviation	1455	336	1391	471	442	468	
Cotton	Number	60	35	95	82	37	119	214
	Mean	732[c]	896	792	867	987	904	
	Standard deviation	342	540	431	427	451	437	
Maize	Number	45	12	57	89	24	113	202
	Mean	1351	812	1238	1006	932	990	
	Standard deviation	2907	409	2593	706	651	693	
Cowpea	Number	9	0	9	15	3	18	27
	Mean	205	0	205	400	323	387	
	Standard deviation	161	0	161	369	183	342	
Rice	Number	2	2	4	23	1	24	28
	Mean	950	550	750	447	640	455	
	Standard deviation	778	354	545	359	0	354	
Mixed or intercropping								
Sorghum	Number	62	13	75	98	35	133	
	Mean	390	525	414	829	637	779	
	Standard deviation	442	407	436	981	808	939	
Pearl millet	Number	11	5	16	21	6	27	
	Mean	577	438	534	566	790	616	
	Standard deviation	331	356	334	500	464	402	
Groundnut	Number	74	6	80	135	12	147	
	Mean	818	678	807	697	938	716	
	Standard deviation	553	527	549	629	649	632	

Continued...

Table 17. *Continued...*

		Clusters						
		Group 1			Group 2			
Crop		Nonusers	Users	Subtotal	Nonusers	Users	Subtotal	Total
Cotton	Number	7	5	12	56	37	23	79
	Mean	1110^c	590	894	757	861	787	
	Standard deviation	265	366	399	458	498	469	
Cowpea	Number	65	14	79	23	5	28	27
	Mean	181	129	172	447	224	407	
	Standard deviation	228	145	216	612	214	565	
Rice	Number	3	1	4	13	2	15	28
	Mean	800	600	1393		1400	1393	
	Standard deviation	1309	0	938	3378	1980	354	

c = significant at 10%.
Source: OHVN survey, 2002.

6.4 Drivers of Uptake of Soil and Water Conservation Technologies, Input Use and Crop Productivity

This section presents the specifications of the input and structural production function models. The variables used in the estimation of uptake, input demand and production functions are elicited.

6.4.1 Specifications of the Models

Uptake of at least one soil and water conservation technology. In the uptake equation, the dependent variable takes the values 0 (no uptake) and 1 (at least one NRM technology used). The commonly used models are the Logit or Probit models. The number of soil and water technologies applied to the plot were fitted using the Poisson regression[8].

Input demand equations. Apart from land and labor, the two major inputs used in the production process were organic and inorganic fertilizers. In the input demand equations, the dependent variables included the value of inorganic fertilizers and the quantity of organic fertilizers per ha[9]. All of these variables are censored at zero; ie, the value of inputs used is zero for a substantial number of plots. The use of the ordinary least squares (OLS) method to estimate parameters in censored regression models leads to biased and inconsistent parameter estimates (Maddala 1983). Hence a commonly used alternative model is the Tobit model, which is a maximum likelihood estimator that accounts for the censoring rule. A drawback of the model (or any

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8. Poisson regression is a form of regression analysis used to model count data and contingency tables. Poisson regression assumes the response variable Y has a Poisson distribution, and assumes the logarithm of its expected value can be modelled by a linear combination of unknown parameters. A Poisson regression model is sometimes known as a log-linear model, especially when used to model contingency tables.
9. Labor demand was not estimated because of the difficulty associated with collecting this data based on recall.

maximum likelihood estimator) is its sensitivity to distributional assumptions. If the error term is not normally distributed and homoskedastic, as assumed by the standard Tobit model, this estimator also yields biased parameter estimates.

An alternative estimator for censored regressions that is robust to such distributional assumptions is the censored quantile regression model (CNQREG), which is a generalization of the censored least absolute deviations estimator of Powell (1984). Its two drawbacks are that the algorithm often fails to converge and the estimator does not account for the sampling probability of the observations in the sample; so the regression results are not representative of the underlying population sampled. The first drawback can be addressed by adjusting the quantile level of the regression; in general, higher quantile levels are needed to estimate the algorithm if a larger fraction of the observations are censored. This points to another drawback of the CNQREG algorithm; namely, that the results of the estimation may vary depending on the quantile level used.

We addressed these issues by estimating the input use regressions using both Tobit models and censored quantile regressions. We report the quantile level at which convergence was achieved, as well as from the Tobit models, and emphasize conclusions that are robust to the model specification. Since the dependent variables take zero values, we could not use a logarithmic transformation of the dependent variable. We therefore estimated these models using untransformed values of the dependent variables and explanatory variables.

Structural production functions. In the specification of the production equation, we used a modified translog functional form, in which the dependent variable and all of the continuous explanatory variables are transformed by their natural logarithms. Such transformations generally improve the performance of linear regression models by transforming the variables towards normal distributions and reducing the sensitivity of the transformed variables to outliers (Mukherjee et al. 1998). We did not include all of the interaction terms or the squared terms normally included in a translog production function, as this leads to severe problems of multicollinearity. Since the study was confined to whether and how organic and inorganic fertilizers interact in the production function, ie, whether they have positive or negative cross productivity effects, only interactions between them were included.

In estimating production equations, the possibility of input variables (inorganic and organic fertilizers) being endogenous arose, meaning that they may be correlated with the error term in the regression because the farmer may have some information about the error term (which we have not observed) when deciding how much of each input to apply. For example, the error term in the production equation may include unobserved (by the researchers) land characteristics or weather conditions that the farmer took into account in deciding how much fertilizer to apply. In such a case, the coefficients of input use in the regression may "pick up" the effect of such unobserved factors. For example, higher fertilizer use may be associated with higher yields in part because farmers apply more fertilizer to better quality plots or when weather conditions are favorable. Thus, in this example, the coefficient of fertilizer in the production function regression would tend to overstate the true partial impact of fertilizer (controlling for other factors) on production. In other cases, the true impact could be underestimated. Though these potential econometric problems are recognized, this report does not address them. Annexure 2 spells out ways of addressing endogeneity problems.

We ran an ordinary unrestricted OLS regression, including all of the exogenous variables specified as explanatory variables and estimated median regression, which is robust to problems of outliers and heteroskedasticity. We laid greater emphasis on results that are robust in the median regression models.

6.4.2 Variables Used in the Estimation of Uptake, Input Demand Equations and Production Functions

Dependent variables. The dependent variables used in the econometric analysis were as follows:

- Whether or not at least one soil and water conservation method was used (0=not used, 1=used) (used in the Logit model)
- The number of soil and water conservation methods applied in the plot (used in the Poisson regression model)
- Crop yield: For sole crop stands (millet, sorghum, maize and cotton) the quantity produced in kg/ha (used in the productivity equation – simple and quantile regressions)
- Inorganic fertilizers: The total value of fertilizers used in FCFA/ha (used in the Tobit and quantile regressions)
- Organic fertilizers: The quantity of organic fertilizer applied in kg/ha (used in the Tobit and quantile regressions).

Explanatory variables. The explanatory variables included the following plot-level, household-level and socio-economic and demographic profiles of households:

Plot-level variables:

- Ln (area of the plot in ha)
- Perceived soil fertility categories (1=poor, 2=average, 3=good, and 4=very good)
- Plot position in the toposequence (1=top, 2=sloped, 3=lowland, 4=top and sloped, 5=sloped and lowland, and 6=top, sloped and lowland)
- Ln (distance of the plot from the residence in km +1)
- Plot status: Collective (0) or private (1)
- Crops grown in the plot (cotton, maize, sorghum, maize, and cowpea).

Household-level variables

- Ln (total cash sales from crops, livestock and off-farm activities in FCFA+1)
- Ln (total area of land cultivated in ha +1)
- Ln (land/labor ratio +1)
- Ln (dependency ratio +1)
- Ln (total value of livestock owned in FCFA+1)
- Ln (total value of traction animal owned in FCFA+1)
- Ln (total value of durable assets in FCFA+1)
- Ln (total value of farm equipment in FCFA+1)
- Total livestock owned in tropical live unit equivalents (TLU).

Characteristics of the household head

- Educational categories (illiterate, primary, secondary, literacy-numeracy training, koranic school, other)
- Ln (age)
- Family size (the number of members in the household)
- The major occupation of the household head (1=agriculture, and 2=other activities)
- Ownership of television or radio in the household provides a proxy for exposure to information.

Clusters
Cluster characteristics - dummy variable (Group 1 and Group 2). Group 1 represents villages with more institutions, located in the more favorable rainfall zone, with relatively better road access, a higher population density and better access to markets than Group 2.

In the adoption and input demand regressions, linear forms of all continuous explanatory variables were used. To account for a possible non-linear response to the age of the household head, the age squared as well as age were included. Logarithmic forms were used in production function estimations.

6.5 Econometric Results

6.5.1 Drivers of Uptake of at Least One Soil and Water Conservation Technology

The results from the Logit model of uptake of at least one soil and water conservation method suggest that the factors that most determine the probability of adoption of at least one soil and water conservation method were: plot area (+), plot status (-), perception of average fertility compared to poor fertility (+), the perception of very good fertility relative to poor fertility (+), position of the plot on the toposequence (+), the value of equipment (+), the value of livestock (-), total cash sales (+), age of the household head (+), the age squared (-), the dependency ratio (+), numeracy and literacy program (+), and farmers' growing crops such as cotton, maize, and sorghum (+) (Table 18).

Compared to poor fertility plots, farmers' perception from average to very good plot fertility increased the probability of adoption. Similarly, the position of the plot on the toposequence relative to the top increased the probability of adoption. In fact, plots positioned on the slope and lowland were largely subject to soil and water erosion and warranted the use of soil and water conservation methods. An increase in the value of equipment will lead to increase in the probability of uptake of at least one soil and water conservation method. Uptake of soil and water conservation options require investment in equipment (such as carts, etc) either to carry stones for stone bunds or stone lines, or to construct small dikes, etc. Increase in total cash sales is likely to increase the probability of adoption. In fact, options to generate cash (liquidity) to pay for labor are essential for uptake of S&WC methods. Similarly, the greater the number of household heads engaged in numeracy and literacy programs and the more educated they were, greater was the probability of adoption. Farmers' engagement in cotton, maize or sorghum was likely to increase the probability of adoption. The dissemination of S&WC methods was linked to the expansion of cotton in the OHVN zone. Maize or sorghum are grown after cotton, thus benefiting from the residual effects of nitrogenous fertilizers in addition to water conservation methods which improve fertilizer use efficiency.

As one moves from collective to individual plots, the probability of adoption is likely to decrease. Households tend to apply fertilizers on collective plots that are basically targeted for cotton production. Coming to the age of the household head, there is an optimum age below which the probability of adoption is likely to increase as age increases and above which the probability of adoption of at least one S&WC method is likely to decrease as age increases.

While all variables are counter-intuitive and consistent with several references, an increase in plot area increases the probability of adoption and an increase in the total value of livestock owned would decrease the probability of adoption. In effect, one would expect that as the plot area increases, it will require more resources to apply soil and water conservation methods,

Table 18. Drivers of uptake of at least one soil and water conservation technology.

	Logit model		Marginal effects		Poisson regression	
Variable	Coefficient	Standard Error	dy/dx	Standard Error	Coefficient	Standard Error
Plot characteristics						
Plot area (ha)	.1511299[a]	.0443694	.0155004[a]	.00459	-.0035331	.0111357
Plot status	-.4709067[b]	.2222222	-.0482979[b]	.02267	-.4192336[a]	.1639141
Average fertility	.4826023[a]	.1627193	.0517778[a]	.01814	.3984251[a]	.1186344
Good fertility	.1913593	.206906	.0205708	.02326	.1547555	.1425176
Very good fertility	1.327977[a]	.4277651	.2123521[b]	.09274	.6678854[a]	.2440744
Sloped	.9599594[b]	.4681177	.1367193	.08592	1.018953[a]	.3577655
Lowland	3.301618[a]	.2621917	.6302842[a]	.04657	2.286779[a]	.1999798
Sloped and lowland	1.194368[a]	.2257662	.1195045[a]	.02154	1.077285[a]	.1934123
Top, sloped and lowland	3.161746[a]	.3057609	.6216425[a]	.05689	2.203206[a]	.2191277
Distance from plot and homestead	-.0393266	.0452353	-.0040335	.00463	-.0101054	.0325361
Household characteristics						
Total cultivated area	.0001294	.0164651	.0000133	.00169	.0679613[a]	.0184272
Value of farm equipment	2.31e-06[a]	5.32e-07	2.37e-07[a]	.00000	1.41e-06[a]	3.00e-07
Value of traction animals	-5.01e-09	4.20e-07	-5.13e-10	.00000	2.09e-07	2.61e-07
Total durable assets	-5.77e-08	6.05e-08	-5.92e-09	.00000	-5.57e-08	5.21e-08
Value of livestock	-2.34e-07[b]	1.10e-07	-2.40e-08[b]	.00000	-1.58e-07[b]	7.25e-08
Total cash sales	2.34e-07[a]	7.11e-08	2.40e-08[a]	.00000	1.97e-07[a]	4.40e-08
Land labor ratio	-.0067958	.0360965	-.000697	.0037	-.0011638	.0259585
Characteristics of Household Head (HH*)*						
Age of HH	.1209417[a]	.0339092	.0124042[a]	.00345	.087222[a]	.0257331
Age of HH squared	-.0010571[a]	.0002898	-.0001084[a]	.00003	-.0007184[a]	.0002149
Dependency ratio	.237835[a]	.083378	.0243932[a]	.00862	.1362743	.0536034
Family size	-.0023471	.0083114	-.0002407	.00085	.0012985	.0056255
Primary school	-.0362482	.0294323	-.0037177	.00302	-.0256934	.0176578
Secondary	.0613896	.0822401	.0062963	.00845	.0315906	.0490972
Numeracy/literacy	.251876[a]	.053297	.0258333[a]	.00549	.1695659[a]	.035631
Koranic school	-.0137479	.0177717	-.00141	.00182	-.0199335[a]	.0075242
Agriculture as the main occupation	.2851428	.3085889.	.0292453	.03162	.041047	.234187.
Television/radio	-.1071634	1896514	-.0107164	.0185	-.1150499	1398298
Crops grown on the plot						
Cotton	1.189045[b]	.491919	.1682892[c]	.0895	.773364[a]	.3675783
Pearl millet	.9908435[b]	.488976	.1373681	.08629	.6072684	.3778797
Groundnut	-.0776038	.4577795	-.0078648	.04583	-.0866895	.3648009
Maize	1.085567[b]	.4753017	.1526293[c]	.08559	.7306968[b]	.3678638
Sorghum	.9798222[b]	.4502383	.1196719[c]	.06433	.7111354[b]	.3507083
Cowpea	.4691935	.5107036	.0562292	.07045	.4512518	.3930668
Cluster (cf. South of the OHVN)						
Village cluster	.0354472	.1512589	.0036259	.01543	.0557743	.1068388
Constant	-8.008001[a]	1.174565			-6.269837[a]	.903841
Number of observations	2052				2052	
Pseudo R2	0.2766				0.2241	
Log likelihood	-717.63406				969.7296	
Wald test [chi2(35)]	359.67[a]					

a = significant at 1%; b = significant at 5%; and c = significant at 10%.

and given the limitations on resources, the probability of adoption of at least one soil and water conservation method decreases. As for the increase in the total value of livestock, it may so happen that large livestock owners keep them far away from their fields and there are no differences between owners and nonowners. The most critical factor in this case was the ownership of carts to carry dung from cattle or small ruminants.

Results from a Poisson regression on the number of soil and water conservation methods used by farmers were consistent with the Logit results, except for the plot area which was not significant but had the intuitive sign.

6.5.2 Inorganic Fertilizers

Inorganic fertilizers refer to all phosphorus or nitrogen-based fertilizers or a combination thereof. Table 19 presents the results from Tobit and median regression models on the intensity of inorganic fertilizer used. We were able to obtain convergence of the censored quantile regressions for inorganic fertilizer use for the 90% quantile level. Several variables were found to be statistically significant (at least at 10% level).

These included household perception of plot fertility level (average and good fertility) (+), plot located in the lowland (+), the value of durable assets owned by households (+), household head with secondary school level of education (+), cotton production (+), pearl millet (-), groundnut (-), cowpea (-) and sorghum (-) production.

These results highlighted the fact that farmers tended to use inorganic fertilizers on cash crops, as in the case of cotton, but not on pearl millet, groundnut, cowpea and sorghum.

The findings with respect to distance from homestead to the plot, plot area, total cultivated area, value of equipment, value of animal traction, total cash sales, total value of livestock, age of household head, dependency ratio and family size were not found to be significant. However, inorganic fertilizer use was positively related to distance because it is easy to transport compared to organic fertilizers.

Table 19. Determinants of inorganic fertilizer use.

	Tobit model		Median regression	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Plot characteristics				
Plot area (ha)	1.049869	2.414638	-3.361635	3.69648
Plot status	17.08608	12.24249	22.24396	14.67022
Average fertility	49.66004[a]	9.598025	49.44647[a]	14.08371
Good fertility	54.20909[a]	11.36773	51.22284[a]	16.24949
Very good fertility	65.49296[a]	24.7493	36.11431	30.64255
Sloped	-4.403287	25.26475	-57.79256	42.95532
Lowland	32.64871[b]	13.30236	31.12333[b]	15.28604
Sloped and lowland	-6.002325	9.660003	-22.11406[b]	11.09083
Top, sloped and lowland	-2.279303	18.13557	19.02529	21.31386
Distance from plot to homestead	3.403171	2.419921	4.089832	3.055238
Household characteristics				
Total cultivated area (ha)	-.8082816	.9136628	.8135124	.8312275
Value of equipment (FCFA)	.000043	.0000282	.0000299	.0000372
Value of animal traction (FCFA)	-.0000231	.0000241	-.000018	.0000282
Value of total assets (FCFA)	2.40e-06	2.00e-06	8.46e-06[a]	1.21e-06
Total value of livestock (FCFA)	-3.03e-06	5.91e-06	2.48e-06	6.74e-06
Total cash sales (FCFA)	1.00e-06	4.16e-06	2.16e-06	2.98e-06
Land labor ratio (ha/adult equivalent)	.2511351	1.774566	-.2935996	1.911567
Characteristics of Household Head (HH)				
Age of HH	-2.350797	1.611347	-3.20964	2.122229
Age squared	.015276	.0136317	.0233268	.0176155
Dependency ratio	-7.435567	5.212107	.3661938	5.705393
Family size	.5801777	.4481027	-.0012179	.4868103
Primary school	1.959678	1.595663	2.058786	2.001445
Secondary school	6.189784	4.394616	9.601643[b]	4.825563
Numeracy/literacy	-.8512888	3.080333	-1.478588	3.651459
Koranic school	.9660461	.8832076	-.0221603	.9282041
Agriculture as the main occupation	29.86849[c]	17.55361	11.39458	18.50966
Television/radios	3.256342	10.41067	-7.382076	12.28777
Cluster (cf. South of the OHVN)				
Village cluster	-7.584673	8.825227	-7.390383	10.79876
Crops grown on the plot				
Cotton	209.516[a]	19.14201	99.11043[a]	20.63027
Pearl millet	-88.49464[a]	23.34547	-130.507[a]	22.53601
Groundnut	-157.1327[a]	19.90138	-170.555[a]	26.66075
Maize	45.64691[b]	19.77112	-4.921717	21.97635
Sorghum	-89.57786[a]	19.0988	-141.2351[a]	21.07163
Cowpea	-159.8246[a]	29.87463	-160.4747[a]	31.28326
Constant	-61.12358	54.76096	183.253[a]	66.52226
Sigma	113.2665	4.035941		
Number of observations	479/1573		1087	
LR chi2(34)	1270.39[a]			
Pseudo R2	0.16120		0.3933	

a = significant at 1%; b = significant at 5%; and c = significant at 10%.

6.5.3 Determinants of Organic Fertilizer Use by Households

Table 20 summarizes the results from the Tobit and quantile regression of organic fertilizer intensities. The quantile regression converged at 90% quantile level. Few results were found to be significant in both specifications. Plot status, plot location on the toposequence (sloped, low land, and sloped and lowland), total area owned, value of equipment, value of animal traction, family size, numeracy and literacy, maize production, and cluster significantly explained the use of organic fertilizers in the Tobit model, whereas plot location in the sloping and lowland toposequences, the value of durable assets, total cash sales, cotton, groundnut, maize and sorghum were the determinants of organic fertilizer use in the Median regression model. The plot location in sloping and lowland toposequence and maize production were found to be consistent. This raises some issues related to the relevance and appropriateness of both models.

Tobit results indicate a negative association between plot status and use of organic fertilizers, suggesting that households tended to use organic fertilizers on collective plots. This is counter-intuitive with the fact that there should be more incentives to improve private rather than collective plots. However, the negative association between total land cultivated and intensity of organic fertilizer use is intuitive as organic fertilizer supply is limited.

There were positive associations between the value of equipment and the value of animal traction and the use of organic fertilizers. The value of equipment which included cart ownership, may largely explain greater use of manure because carts are used to transport manure. The positive association with family size may be related to the need for more labor to handle and carry dung from cattle and small ruminants in the fields, especially when family labor constitutes the major stock of labor. Households who went through literacy and numeracy programs used more organic fertilizers. More organic fertilizer was used in the environment with better access to markets, institutions, roads, etc.

The positive but insignificant association between occupations other than agriculture and organic fertilizer use was expected. We did not expect households engaged in other occupations to have higher opportunity costs of labor; hence they were less likely to use labor-intensive agricultural practices such as organic fertilizer.

Formal education (primary and secondary school, etc) was not associated with organic fertilizer use. Education in the form of numeracy and literacy had positive associations with organic fertilizer use, suggesting that their content may have had an important bearing on agricultural practices and influence awareness of or attitudes about land management practices. Perhaps other forms of education besides formal schooling are influencing such awareness and attitudes.

6.5.4 Determinants of Crop Productivity

This section presents the determinants of crop productivity of cotton, maize, pearl millet and sorghum. Results are presented for only sole crops during 2001/02.

Cotton productivity. Results from the median regression on productivity (yield) are presented in Table 21.Variables having a statistically significant impact on cotton production included the amount of inorganic fertilizer used (+), the use of stone lines in the plot (+), plot area (+), the perception of good fertility (+), plot status (-), total cash sales (+), ownership of radio or television (+) and village cluster.

Table 20. Determinants of organic fertilizer use by farmers.

	Tobit model		Median regression	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Plot characteristics				
Plot area (ha)	87.70231	175.0807	-320.4855	268.9927
Plot status	-3617.782[a]	1087.102	-1705.223	1990.004
Average fertility	1040.259	662.6055	554.6712	1078.558
Good fertility	46.28283	830.923	9.501003	1210.044
Very good fertility	4594.9	1565.619	3559.265	2321.421
Sloped	3621.725[c]	1997.89	4572.824	3053.031
Lowland	2809.604[a]	1075.234	2559.108	2026.219
Sloped and Lowland	3339.543[a]	836.15	3099.824[c]	1911.333
Top, sloped and lowland	1996.939	1453.486	2466.043	2617.142
Distance from plot to homestead	160.652	171.0645	45.32915	219.34
Household characteristics				
Total area owned (ha)	-209.1664[a]	80.76611	-127.026	122.9218
Value of equipment (FCFA)	.0043702[b]	.0019656	.0016641	.0030966
Value of animal traction (FCFA)	.0049242[a]	.0017011	.0013449	.0024399
Value of total assets (FCFA)	-.0001099	.0001468	.0006962[a]	.0001381
Total value of livestock (FCFA)	.0000177	.0003911	.0001955	.0004923
Total cash sales (FCFA)	.0002645	.0004315	.0014421[a]	.0003987
Land labor ratio (ha/adult equivalent)	56.99828	134.1525	14.23441	140.749
Characteristics of Household Head (HH)				
Age of the HH	110.301	117.5323	129.1081	241.1164
Age squared	-1.515152	1.01452	-1.400147	2.03298
Dependency ratio	-304.1869	460.8881	116.2253	664.187
Family size	65.29773[c]	35.53511	49.81002	45.39369
Primary school	-245.0848	131.8585	-130.7665	193.7793
Secondary school	226.7616	269.3358	-41.32899	203.7963
Numeracy/literacy	547.529[b]	223.5775	409.512	322.2258
Koranic school	-203.4487	139.4271	-76.74644	229.5123
Agriculture as the main occupation	882.2418	1254.836	-663.6903	1443.641
Television/radios	910.6854	694.9379	984.4896	981.2219
Cluster (cf. South of the OHVN)				
Village cluster	-1936.502[a]	605.5786	-516.5094	859.7914
Crops grown on the plot				
Cotton	3492.39	2281.25	4214.437[c]	2427.611
Millet	1352.481	2380.559	2988.354	2969.083
Groundnut	-1326.928	2364.126	6754.647[b]	3092.743
Maize	6255.632[a]	2291.695	5427.731[b]	2504.996
Sorghum	2560.504	2262.083	3927.69[c]	2308.758
Cowpea	575.8957	2465.642	3229.871	3244.94
Constant	-12829.53[a]	4517.491	-7003.204	7513.073
Sigma	5982.151	393.5984		
Number of observations	162		643	
Pseudo R2	0.0590		0.1372	
LR chi2(34)	239.81[a]			

a = significant at 1%; b = significant at 5%; and c = significant at 10%.

Most of these results are consistent with expectations. The use of fertilizers and stone lines explain the productivity of cotton. There are interlinked contracts between input and product markets. Farmers are provided fertilizers and are bound to sell cotton to the parastatal company via intermediaries. OHVN has been aggressively promoting stone lines and bunds in the OHVN region.

Table 21. Determinants of cotton productivity.

	Ordinary regression		Median regression	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Inputs				
Ln (qty of inorganic fertilizers)	.0797943	.0833774	.1892714[a]	.072048
Ln [qty of organic fertilizers (kg/ha)]	-.1218489	.2710331	-.042893	.3299455
Interaction of organic × inorganic fertilizers	.1001873	.1656488	.0355797	.198119
Dummy for hired labor	.0102159	.1348516	-.208601	.1638098
Ln (family size)	-.1425751	.6854873	-.147584	.8780462
Ln (no. of adult equivalents)	.18399	.7574507	.1347091	.9915364
Stone bunds	-.0917601	.1761542	.0865555	.1655214
Branch barriers	.0945222	.25142	-.2321198	.3989578
Stone lines	.4702097[a]	.1127303	.2673858[b]	.1218955
Vegetative bands	.0356998	.1923505	.0107886	.1685548
Plot characteristics				
Ln (plot area)	.3442235[b]	.139368	.3343592[b]	.1516013
Average fertility	.1032552	.2001595	.0321027	.1118784
Good fertility	.3509985[b]	.1585893	.1820062[c]	.1057884
Very good fertility	.3688416[b]	.181341	.3681549	.3287389
Plot status	-.4527672[a]	.150421	-.542819[a]	.1597058
Household characteristics				
Ln (value of animal traction)	-.0035754	.0211124	.0163894	.013495
Ln (age of household head)	.2172454	.2005958	.0745232	.1942849
Ln (total cash sales)	.1122902[c]	.058208	.051215[b]	.0256155
Ln (total assets)	.1419929	.0878844	.1416824	.0960268
Ln (dependency ratio)	.0540144	.3834956	.0246373	.4230937
Televisions/radios	.1854831[c]	.0956935	.241695[c]	.1410637
Region (cf. South of the OHVN)				
Ln (population size)	.2208463[b]	.0971856	.1859741[b]	.0902404
Village cluster	.0414543	.059534	.0037109	.0541534
Constant	1.437586	1.274053	2.733993[c]	1.270687
Number of observations			268	
Pseudo R2			0.2916	

a = significant at 1%; b = significant at 5%; and c = significant at 10%.

Table 22. Determinants of pearl millet productivity.

	Ordinary regression		Median regression	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Inputs				
Ln (qty of inorganic fertilizers)	.021656	.0736163	-.0474645	.0754807
Ln [qty of organic fertilizers (kg/ha)]	.0418927	.0475665	.0456334	.0378224
Interaction of organic × inorganic fertilizers	.0323248	.0859427	.0754878	.0584001
Dummy for hired labor	-.0893384	.2609586	-.3068964	.4053339
Ln (family size)	.8736255	1.63987	1.220892	.8994836
Ln (no. of adult equivalents)	-.758519	1.938262	-1.046115	1.004122
Cordons	.3434752	.2602958	.0019339	.3233197
Branch barriers	.549318	.5748053	.289516	.705252
Stone lines	-.2607236	.5454182	-.1965894	.4442659
Vegetative bands	-.1924524	.4990209	-.4230159	.5044228
Plot characteristics				
Ln (plot area)	.2375249	.3164508	-.0621728	.1858816
Average fertility	.2903453[c]	.1614381	.5421584[a]	.1544106
Good fertility	.3554038	.3756846	.3792993	.3351487
Very good fertility	.7412371	.4710718	.9620345[c]	.5605038
Plot status	.0273283	.318085	-.01044	.9739668
Household characteristics				
Ln (value of animal traction)	.0954663[a]	.0310035	.0348868[c]	.0209675
Ln (age of household head)	-.0491829	.4479544	-.0014526	.3031371
Ln (total cash sales)	-.0379002[b]	.0134042	-.0382416[b]	.0182092
Ln (total assets)	-.0403067	.2104625	.1755162	.1315084
Ln (dependency ratio)	-.1330709	.5543346	-.1332103	.3500959
Televisions/radios	.8400167[a]	.2852977	.3109293	.2110839
Region (cf. South of the OHVN)				
Ln (population size)	.156492	.0986247	.1373506	.1343662
Village cluster	.4668349[b]	.1706178	.3606537[c]	.2058304
Constant	3.357178	2.00756	1.173804	2.21967
Number of observations	175		175	
R-squared/Pseudo R2	0.3041		0.2565	

a = significant at 1%; b = significant at 5%; and c = significant at 10%.

Although we did not find a significant inverse farm-size productivity relationship, results for millet-sorghum-cowpea indicate that labor constraints are affecting yields of this crop mix, given the positive effect of the labor/land ratio and negative effect of the dependency ratio. Thus, labor-constrained households found it more difficult to produce this crop mix than other households.

Pearl millet productivity. Results from the median regression on pearl millet yield are presented in Table 22. Variables having a statistically significant impact on pearl millet production included household perception of plot fertility status (+), the value of animal traction (+), total cash sales (-), and village cluster.

Table 23. Determinants of sorghum productivity.

	Ordinary regression		Median regression	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Inputs				
Ln (qty of inorganic fertilizers)	.0241009	.0323172	.0139187	.0378752
Ln [qty of organic fertilizers (kg/ha)]	.0148375	.0179229	.018046	.0218088
Interaction organic × inorganic fertilizers	-.0067141	.0280583	-.0049584	.0346011
Dummy for hired labor	-.0436016	.1034938	-.222753[a]	.1365541
Ln (family size)	-.1303386	.4001325	-.5358726	.6397435
Ln (no. of adult equivalents)	.3360964	.4436996	.8924723	.6965351
Cordons	.1933983	.1244802	.1737438	.1766987
Branch barriers	-.1259093	.2071839	-.2463136	.3105326
Stone lines	.1369705	.0950526	.1768171	.1571205
Vegetative bands	.2570557[c]	.1492098	-.1531043	.2401056
Plot characteristics				
Ln (plot area)	.2867858[b]	.1285844	.2561166[b]	.1148706
Average fertility	.2696207[a]	.060058	.2751115[b]	.1165056
Good fertility	.2048341	.1389324	.3024866[b]	.1265294
Very good fertility	.5916441[a]	.1867008	.7797559[c]	.402761
Plot status	-.6579947[a]	.2316301	-.7994844[a]	.1706753
Household characteristics				
Ln (value of animal traction)	-.0086472	.0094441	-.0060035	.0100047
Ln (age of household head)	-.0659647	.1887172	.0067105	.1501648
Ln (total cash sales)	.0410456[a]	.0131708	.0301204[b]	.0128666
Ln (total assets)	.111601	.0769248	.0520597	.0705171
Ln (dependency ratio)	.279204	.192222	.4179726	.2941479
Ln (population size)	.0101351	.086165	-.0615728	.0597106
Televisions/radios	.364722[a]	.128523	.3608412[a]	.1097432
Region (cf. South of the OHVN*)*				
Village cluster	.5256597[a]	.1397066	.5445893[a]	.1015898
Constant	3.83339[a]	1.020391	5.142666[a]	1.007614
Number of observations	557		557	
R-squared/Pseudo R2	0.3201		0.2234	

a = significant at 1%; b = significant at 5%; and c = significant at 10%.

Sorghum productivity. Results from the median regression on sorghum productivity are presented in Table 23. Variables having a statistically significant impact on sorghum production included the dummy on hired labor (-), household perception of plot fertility (+), plot area (+), total cash sales (+), ownership of televisions/radios (+), and village cluster.

Maize productivity. Results from the median regression on maize productivity (yield) are presented in Table 24. Variables having a statistically significant impact on maize production included plot area (+) and the perception of good fertility (+).

Table 24. Determinants of maize productivity.

	Ordinary regression		Median regression	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
Inputs				
Ln (qty of inorganic fertilizers)	-.0144852	.0487762	.0398287	.0371117
Ln [qty of organic fertilizers (kg/ha)]	.0265707	.0193723	.0146279	.0256073
Interaction organic × inorganic fertilizers	.010862	.021274	.0027801	.0220406
Dummy for hired labor	-.2055647	.2134822	-.2877971	.2941711
Ln (family size)	-2.791289[b]	1.092563	-1.59135	1.44776
Ln (no. of adult equivalents)	3.02123[b]	1.244861	1.637874	1.649967
Cordons	.1112665	.156704	.2993855	.2696792
Branch barriers	.3760178	.2615802	.0664571	.56378
Stone lines	.0985559	.1464474	-.0701219	.2382881
Vegetative bands	-.0563545	.3080523	.3989596	.6665389
Plot characteristics				
Ln (plot area)	.5961983[c]	.3013694	1.110882[a]	.313316
Average fertility	.4247568[b]	.2032408	.1946241	.1658554
Good fertility	.5999518[b]	.2386002	.3917452[b]	.1826517
Very good fertility	.4788132	.4982902	.4543283	.8723966
Plot status	-.2210899	.3885742	-.7807419	.7815469
Household characteristics				
Ln (value of animal traction)	.015197	.0150351	.0175968	.0148425
Ln (age of household head)	.3237595	.2821262	.0662236	.2447486
Ln (total cash sales)	-.0025893	.0115258	.0134555	.014709
Ln (value of total assets)	.1842314[a]	.0558426	.1191101	.0977179
Ln (dependency ratio)	1.32411[b]	.5479992	.7747721	.7428817
Televisions/radios	.0571327	.119689	-.0180656	.1665337
Region (cf. South of the OHVN)				
Ln (population size)	.0683459	.0857184	-.0391428	.0823731
Village cluster	.1801628	.137401	.2204952	.181622
Constant	2.331615	1.778948	4.873585[a]	1.694991
Number of observations	214		214	
R-squared/Pseudo R2	0.3195		0.2547	

a = significant at 1%, b = significant at 5% and c = significant at 10%.

7. Conclusions and Implications

This study shows that 40% of the households were using soil & water conservation methods in the OHVN zone. A range of factors explained the uptake, first among which was the process used to disseminate technologies.The natural resource management program of the OHVN has been largely involved in disseminating S&WC methods, especially in the South of the OHVN zone. This region was more suitable for cotton production which was the major focus of OHVN intervention. The technologies disseminated in more than 50% of the selected villages included stone lines, stone bunds, living hedges, and branch barriers and were those mainly used by the households.

The levels of endowment in livelihood assets and transforming structures such as markets and institutions at the village level were major drivers to uptake. This was the case in the South of the OHVN zone, where road access was easier, soils were suitable for cotton production, there were more input and product markets, access to fertilizers even on credit was provided by OHVN, and there were more institutions dealing with health, education and farmers' organization than in other parts of the OHVN zone. Men reported cotton, groundnut, and cereals as the major drivers of village economies whereas women claimed groundnut and shea butter to be the major drivers. At the household level, stone lines and stone bunds were the most widely adopted technologies by 22% and 11% respectively. Vegetative bands, wood barriers, and living fences were adopted by more than 5% of the households. Adoption was concentrated in the Southern part of the OHVN zone where the OHVN program disseminated technologies. Users of S&WC technologies had more livelihood assets than nonusers. On an average, users had a greater work force, more educated members, and owned more land, livestock, agricultural equipment, cash income and consumable assets than nonusers. Most farmers reported that these technologies, with the exception of half-moons generated productivity gains estimated between 20 and 60%.

At the plot level, the same trend was observed as at the household level. Results indicated that households applied at least one soil and water conservation technology in 20% of their cultivated plots. Stone lines and stone bunds were used on 10% and 5% of the plots respectively. Users of S&WC technologies applied more fertilizers per ha than nonusers; 53 kg/ha against 30 kg/ha. Fertilizer application differed significantly by crop. Fertilizer use intensity was high in high-value crops such as cotton and maize. But farmers used little fertilizers in other crops. Plots largely differed based on their characteristics but there were no significant differences between users and nonusers, except in their perception of fertility and production levels.

Households' perception of changes or productivity levels did not necessarily tally with estimated yields of major crops or farmers' perception of welfare changes. Except for sorghum and cotton, there were no significant differences in yields between users and nonusers of S&WC technologies. This raises questions on productivity gains derived from using these technologies. This question is difficult to address because of lack of baseline data to compare the situation before and after the project. It may well happen that the productivity in some areas was very low and that with the use of S&WC methods it increased significantly. This may be the case in the South of the OHVN zone where water erosion is more important than in other OHVN regions. In addition, due to lack of monitoring and evaluation of technologies, it was difficult to assess trends in yields in the OHVN region. Overall, 75% of household users of S&WC technologies reported having accumulated more assets and were more food secure since 1995. This may suggest that the use of S&WC methods had positive impacts. In addition, more than 80% of the households claimed large improvements in health, education, and access to potable water. However, it is difficult to attribute changes in overall well-being to the impact of S&WC technologies alone. Many other interventions might have been partly responsible for these changes. A baseline study is necessary to better assess the impact of soil and water conservation measures on productivity gains.

This report provides a descriptive analysis and static view on uptake of soil and water conservation technologies, comparing users and nonusers at the univariate level. This may disguise the correlations that exist between factors driving uptake. Further analysis is required to examine the factors driving uptake, taking into account the possible relationship between factors. In addition, few studies have addressed factors that may explain household perceptions of changes in livelihood outcomes. These factors may help better target households where such interventions are the most needed. A range of research questions remained, such as:

- What are the processes and determinants of uptake that are dynamic in nature?
- What was the decision-making process followed by farmers who adopted and sustained the use of soil management/fertilizer technologies over time? Our hypothesis is that there was some sequence of events/decisions over a period of several years that led to sustained adoption of these technologies. The objective was to go beyond the type of information that comes from adoption models by viewing the decision as a process and developing a better understanding of when and how the process is sustained or, in the case of disadoption, when and how the process breaks down.
- What are the criteria that farmers used to evaluate the impacts of soil management/fertilizer adoption? What was the relative importance of different criteria [food security, yields, cash income, more secure land tenure (i.e., maintaining soil quality reduces need to clear new land), etc.]?

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Annexure 1. Soil & Water Conservation Technologies

Dikes: Dikes are non-permeable and thus serve to retain water, but can consequently cause water logging and soil degradation (Ouédraogo 2005). Their time-consuming maintenance and problems with water logging limit their use, except in the production of rice.

Vegetative strips or bands: These are strips of land planted with perennial grasses. The grass cover protects the soil against wind and water erosion. They can stand alone or be used in combination with stone bunds, in which case the grass strips should be planted on both sides of the stone bund. Grass strips combat erosion and the grasses can also be used to produce handicrafts such as baskets or serve as roofing material. Its disadvantage lies in the fact that the seeds can infest the fields, thereby requiring extra weeding. Moreover, they provide a hiding place for snakes. Seeds were distributed freely in some villages in the past, causing problems of dependency. Today farmers complain that seeds are not available.

Half-moons: Half-moons are earthen ridges in the shape of a half moon, with a diameter of four meters inside which the crop is planted. Earth in front of the half moon is dug to a depth of 15-25 cm, which is then used to create the ridge built along the slope of the plot in order to retain water. During years of low rainfall, the technique is useful in promoting infiltration of water inside the half-moon. Sometimes the half-moon is combined with the application of organic fertilizer to the plant (Ouédraogo 2005). Half-moons are considered labor intensive and uptake is low in the OHVN zone since there is enough rainfall to allow for cultivation without them.

Living hedges: Planting (living) hedges helps preserve soil and protect crops (Bandra and Batta 1998). Hedges form barriers to reduce wind and water erosion, which can lead to improved yields through increases in organic carbon and total N in the topsoil (Bationo et al. 1998). If planted densely enough, they can protect crops from grazing livestock. Hedges can stand alone or in combination with earthen dikes or stone bunds. Perennial species are preferred for hedging, as are species which offer additional advantages of providing forage and roofing material (Ouédraogo 2005). In Mali, *Jatropha curcas* is widely grown and used as living hedges. Women collect its seeds to make soap which is sold. The possibility of producing (lamp) oil and biodiesel from Jatropha seeds has not been explored by farmers since they lack the required machinery to press the oil.

Stone bunds/rock bunds/contour bunds/stone lines: All four terms refer to technologies involving the placing of stones in a continuous line. Stone lines are a traditional and simple technique used to describe short rows of stones (a few to a few tens of meters) in places where runoff water concentrates and tends to form rills. The practice reduces runoff and erosion and retains organic matter in the field (Muzzucato and Niemeijer 2000). Stone or rock bunds and contour bunds refer to several layers of stones placed along a contour line and involve multiple stones placed on top of each other. Stone bunds are usually stronger, longer, higher and more effective in combating erosion than stone lines (Muzzucato and Niemeijer 2000). The bunds reduce the force of water runoff and encourage infiltration, creating a micro-climate that favors the establishment of natural vegetation after the rainy season (Bandra and Batta 1998). Stone bunds can be considered an improvement on earthen dikes, which may have the disadvantage of high maintenance costs and instability under intense rainfall (Hulugalle 1989). Stone bunds and lines are ideal since they do not cause waterlogging as impermeable earthen dikes do (Ouédraogo 2005).

Branch barriers. Also known as wood barriers, they are installed where runoff water concentrates and tends to form rills. They reduce runoff and erosion and retain organic matter in the field, while increasing soil moisture (Muzzucato and Niemeijer 2000). Branch barriers are a newly introduced, non-traditional technique in most villages. However, a major limitation of barriers of dead plant material is that they last only one year; and hence are considered non-sustainable by farmers. They also attract snakes. Where stones are scarce, they do offer advantages. The barriers are quick to establish and do not require the use of a cart, thus making it attactive to very poor farmers.

Annexure 2. Addressing the Potential Endogeneity of Input Variables in the Production Function

These could be addressed in a few ways. First, we could include indicators of plot quality, such as soil texture and perceived fertility, in the regression model to reduce the problem of unaccounted-for plot quality characteristics. In effect, the indicators that we observe probably don't perfectly account for all plot quality characteristics that influence input use and production; so there may still be an endogeneity bias. We can use the generalized method of moments (GMM) estimator to estimate the production function and test for non-correlation between the error term and the explanatory variables using the "C test" for orthogonality (Baum et al. 2002; Davidson and MacKinnon 2004). We can test the validity of the overidentifying restrictions in the GMM model using Hansen's J test, and the relevance of the excluded instrumental variables as predictors of the potentially endogenous explanatory variables. We can test for the validity of the overidentifying restrictions in the regression models and the lack of correlation between the input variables and the error term in the regression. If this holds, the model will be valid for treating inputs as exogenous.

The overidentifying restrictions imposed on the GMM models for the production function are based on theory and preliminary statistical testing of a larger model. Theoretically, many variables should affect crop production on a particular plot only by affecting the farmer's use of inputs. The amount of liquidity generated and ownership of durable assets not directly used in crop production are all examples of variables that should not directly affect crop production. However, if productive inputs, land quality or other factors directly affecting production are not perfectly measured, variables such as access to the amount of liquidity and the others mentioned above may have significant impacts on production, even after controlling for input use, because they may act as proxies for other factors that directly affect production. For example, perception of plot fertility level may have different unobserved quality characteristics.

Due to these considerations, we can run an initial unrestricted OLS regression for equation, including all of the exogenous variables specified as explanatory variables. Then, we will use the Wald tests in the unrestricted model to identify variables among those believed not to have a direct effect on production that were jointly statistically insignificant and which could therefore be dropped from the model. If our models passed these Wald tests as well as the C and J tests, and because these exclusion restrictions are for variables that we believe for theoretical reasons did not belong in the model, we will be confident that the restrictions used to improve model identification are valid.

About ICRISAT

ICRISAT
Science with a human face

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 644 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Centers of the Consultative Group on International Agricultural Research (CGIAR).

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