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Picturing Adoption of Below-Ground Biodiversity Technologies among Smallholder Farmers around Mabira Forest, Uganda

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Summary

Faced with a multitude of soil and water amendment technologies, farmers have the task of choosing the technologies to adopt for ensuring subsistence and income sustainability. In 2008, a study to characterize the farmers was conducted around Mabira Forest, to assess the adoption of soil technologies fostering Belowground Biodiversity (BGBD). Eighty-four households (38 participating and 46 non-participants) from four villages were randomly selected and interviewed. Results showed that the adoption pattern was significantly driven by farm size, labor, household size, age and wealth status of the house. Also important were farm location, gender of household head, primary occupation, soil and water conservation technologies training, land tenure, and social capital. For the few current adopters, there was a perceived increase in labor demand but overall productivity was higher, partly resulting from increased crop productivity due to soil fertility enhancement and soil structure modification. It is therefore concluded that, around Mabira forest, BGBD technologies will be adopted by farming households with sufficient land, labor and social capital.

Résumé

Images d'adoption des technologies de la biodiversité du sous-sol parmi les petits exploitants agricoles dans le paysage de la forêt de Mabira, Ouganda

Face à une multitude d'amendement des sols et des technologies de l'eau, les agriculteurs ont la tâche de choisir les technologies à adopter pour assurer la subsistance et un revenu durable. En 2008, une étude a été menée auprès des fermiers de la région de la forêt de Mabira, afin d'évaluer l'adoption des technologies des sols. Quatre-vingt-quatre agriculteurs, choisis au hasard, ont été interrogés. Les résultats ont montré que la taille agricole a significativement influencé le modèle d'adoption, le travail, la taille du ménage, l'âge et le statut de la richesse de la maison. Sont aussi importants la situation géographique de la ferme, le genre de ménage, l'occupation principale, le sol et la formation des technologies de l'eau, le régime foncier et le capital social. Pour les quelques cours à adopter, il y a eu une augmentation de la demande de main-d'œuvre, mais la productivité globale a été plus élevée, résultant en partie de l'augmentation de la productivité des cultures en raison de l'amélioration de la fertilité des sols et de la modification de la structure du sol. Il est donc conclu que, dans la région de la forêt de Mabira, les technologies BGBD seront adoptées par les ménages agricoles avec suffisamment de terres, de main-d'œuvre et le capital social.

Introduction

Evidence of land degradation in Uganda is widespread (12), partly because of limited use of fallow, low use of inorganic or organic sources of soil nutrients, poor fertility management practices and remarkable failures in the adoption of soil and water conservation (SWC) technologies (12). Fertilizer prices have risen sharply in Uganda, and hence, farmers are only able to purchase very little fertilizer, if any at all. Recently, a global project funded by the Global Environmental Facility (GEF), the Conservation and Sustainable Management of Belowground Biodiversity (CSM-BGBD) has come up with sustainable strategies to address this anomaly. In Uganda, the project is working with farmers and other stakeholders, to identify technologies that enhance and conserve BGBD but simultaneously maintain sustainable agricultural productivity.

The Project is focusing on nutrient acquisition by legume modulating bacteria and Arbuscular Mycorrhiza Fungi (AMF), soil structure modification, particularly using earthworms and organic matter enrichment, legume nodule bacteria for improved nitrogen

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uptake, biological control of termites and other SWC technologies. These technologies enhance agricultural productivity, pest resistance, conservation of nutrients and soil life. They use biodiversity to enhance agro ecosystem function, allowing farms to develop their own soil fertility, plant health and sustained yields. The AMF technology involved the use of the fungus as a nutrient trap to improve banana standing crop, while the soil structure modification demonstrated the use of earthworm inoculation, maize stover and mucuna cover crop to improve the soil structure and crop productivity. The legume nodule bacteria was inoculated as a biofertilizer onto the planting seeds to stimulate nodulation, while Metarhizium fungus was applied as biocide in the control of termites in the maize crop.

As BGBD-Uganda works with farmers to develop and diffuse these technologies, several farmers volunteered to participate in on-farm farmer managed trials. Because of the limited resources of individual farmers and due to the fact that the community is very group-oriented in many aspects, we used group approach to participatory research and extension (5, 16). We helped farmer groups to develop group actions for the demonstrations, set objectives, plan activities and provide information for decision-making. It was envisaged that using this participatory approach, technology adoption could be enhanced as observed elsewhere (5). However, a decision to adopt a technology is a complex process during which a farmer looks at several issues that benefit him against the losses (costs) and risks associated with the technology (9). Since the inception of the CSM-BGBD technologies, little information was available on their performance, diffusion and integration in the area.

Several hypotheses have been put forward to explain the process and driving forces for the adoption of soil and water conservation practices, yet there is lack of accurate information on the determinants of these investments. One element that is hypothesized to have a bearing on soil conservation adoption is social capital (6), which is generally interpreted as a degree of trust, cooperative norms, and networks and association within a society. The generation of social capital is hypothesized to enhance collective efforts for natural conservation (14, 15). However, it is not immediately obvious that investment in soil conservation requires, or is enhanced by, investment in social capital at the community level (6).

Therefore, the aim of this study was to test the applicability of the group approach as a tool to enhance the adoption of conservation practices suited to the needs of farming communities in Mabira landscape. The study objective was to assess and isolate the factors that influence the process of technology uptake by farmers. Since the CSM-BGBD project promotes simple conservation practices in Central Uganda by supporting communities, thus augmenting social capital, the study also intended to provide a better understanding of the role of social capital in the adoption/practice of CSM-BGBD technologies.

Materials and methods

1. Study area

Mabira Forest Reserve (29,974 ha) is the largest block of moist semi-deciduous forest remaining in the central region of Uganda (3). It is partly located in the northern Lake Victoria shoreline that is shared by Kenya, Uganda and Tanzania, and is also drained by streams that flow into river Nile; making Mabira an important ecosystem providing hydrological and biodiversity services in the Nile and Lake Victoria basin (Figure 1). Biodiversity of Mabira ecosystem is categorized as a globally-threatened Guinea-Congo forests biome species.

The increasing population pressure (235 people per km^2) in the 27 enclaves and vicinity exerts a high pressure on the land, firewood, building poles and non-timber forest products. Annual timber production, which began in 1900s, is registered at about 4,284 m^3 over the period 1994–96.

The forest is largely accessible because of the presence of village enclaves and access roads leading to them. Potentially, it is economically very important to the communities around, and for the two nearest towns

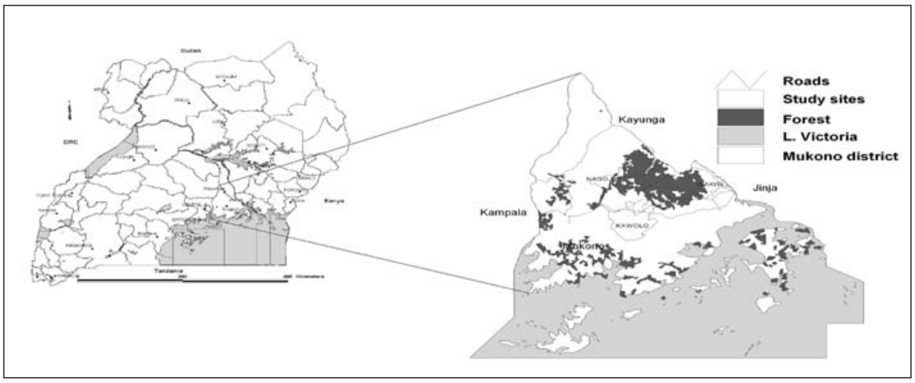

Figure1: Map of Uganda showing the location of Mabira forest and the study site.

namely Jinja and Kampala. Agriculture is the main economic activity in the area, with cassava, sweet potatoes, maize, millet, groundnuts, pease, soya beans, bananas, simsim, and yams being the main food crops grown. The cash crops include; cotton, coffee, sugarcane and tea. Fruits and vegetables are also widely grown in the area: tomatoes, onions, pineapples, vanilla, passion fruits and cabbage being the commonest.

2. Survey

The survey was carried out between April and August 2008 in the four Villages: Bulyantete, Kyambogo, Natiole and Nagojje, where the CSM-BGBD trials were carried being out. All farmers participating in the trials were purposely selected and interviewed in order to assess the extent to which they had integrated the developed technologies into their farms. Thirty eight farmers practicing CSM-BGBD technologies were purposely selected and compared with 46 non-participating farmers randomly selected from a sample frame of all households in the study area. The sample frame was developed for each village with the help of village elders and frontline extension agents of the Ministry Agriculture, Animal Industry and Fisheries (MAAIF). A household was targeted as the basic unit of information and data for the survey. The data were collected by enumerators using a structured questionnaire. Among the data types sought were the farm and farmer characteristics such as farm size, key enterprises, and age, sex, and composition of household members.

The study explored three interrelated questions related to SWC technologies: (a) what were the unique attributes of the CSM-BGBD and other SWC technologies adopters (b) what were the factors influencing individual social capital? (c) How did household attributes and social capital affect adoption of the CSM-BGBD and other SWC technologies? These included households already adopting CSM-BGBD SWC technologies on at least part of their farms, and other community members participating but not yet practicing the technologies on their farm. A one-hour questionnaire was administered to each household from the stratified random sample of 84 households drawn from communities around Mabira forest reserve.

Following Cramb (6), social capital was measured by the number of groups to which the household head belonged. This number varied from 1 to 5 and included a range of agricultural, forestry, conservation, indigenous, cooperative, and other community groups. Those who belonged to 1-2 groups were classified as low social capital, while those who belonged to more than two groups as high social capital members.

Descriptive statistics (frequency counts, percentages and means) combined with student t-test and Chi-square test was used to test for the significance of the difference or associations in the adoption of the soil conservation technologies, respectively. It was also assumed that both participating and non-participating farmers could adopt all or some components of the technologies and incorporate them into their farming systems.

Results and discussion

1. Segregating Adopters and Non-adopter farmers

Characteristics of farmers and farm resources are important in technology development and transfer. These variables are used to characterize farming systems into target groups in the process of disseminating technologies. Some of the characteristics used included sex, age, family size, access and control of resources, employment, and amount of resources at the disposal of farmers (Table 1a). In this study, the most significant qualitative characteristics that distinguished adopters from non-adopters were training in soil and water conservation technologies ($P \leq 0.000$), land ownership ($P \leq 0.000$), quality of housing material or perceived wealth status ($P \leq 0.01$), household location ($P \leq 0.02$), other occupations ($P \leq 0.04$) and gender of household head ($P \leq 0.043$).

Sixty-seven percent of the adopter had received previous training in soil and water conservation technologies, against 33% non adopters. The majority of the adopters (85%) either owned or hired their land for agriculture, as compared to 87.5% of the non adopters who hired their agricultural land. The majority of the households adopting the technology (63.2%) was perceived to be wealthy members of society residing in bricks houses, with iron roofs and cemented floors as compared to the 36.8% non adopters. Differences in the household's access to land and labor resources, financial and commodity markets, significantly influence cultivated land size, kind of crops planted, and farm income (4). Most of the non adopters (83.3%) were peri-urban dwellers as compared to the 16.7% technology adopters. Likewise the, most non adopters (71.4%) had other forms of employment in addition to farming, as compared to the adopters (26.6%). Gender of the household head was a significant segregate of the adoption potential: 63% percent of the male headed houses were non adopters, while 60% of the female headed households were adopters. Gender of the household head plays an important role in the productivity of smallholder farming systems. Demographic attributes of education level, occupation, ownership of livestock were not statistically distinct between the two groups.

The most significant quantitative characteristics that distinguished adopters from non-adopters were age of household head (HHH), number of rooms in a house, household size, adult females, children (7-17), and availability of labor and farm size (Table 1b). Older household heads were more inclined to adoption of the CSM-BGBD than young heads ($P \leq 0.0001$). This implies that as the farmer gets older he/she tends to intensify adoption of innovation in his/her farm. We simply attribute this to experience of the farmer in

Table 1 a

Qualitative household characteristics for the Non-Adopter and Adopter Farm Households for the CSM-BGBD technologies (N= 84)

Parameter	Non-Adopters (%)	Adopters (%)	Significance (X^2, $p \leq 0.05$)
Location			0.02
Urban	0.0	100.0	
Peri-Urban	83.3	16.7	
Rural	42.9	57.1	
Gender			0.043
Male HHH	63.0	37.0	
Female HHH	40.0	60.0	
Marital Status			0.251
Married	53.6	46.4	
Single	71.4	28.6	
Divorced	100.0	0.0	
Widowed	40.0	60.0	
Education			0.134
No formal Education	42.0	57.1	
Primary Education	63.6	36.4	
Secondary Education	54.5	45.5	
High School Certificate	0.0	100.0	
Diploma/ Degree	0.0	100.0	
Housing Material (Wall)			0.01
Mud and Wattle	76.2	23.8	
Cement	0.0	100.0	
Straws	0.0	100.0	
Bricks	36.8	63.2	
Housing Material (Roof)			0.02
Iron Sheets	48.6	51.4	
Straws	100.0	0.0	
Housing Material (Floor)			0.015
Mud and Wattle	58.3	41.7	
Cow dung	100.0	0.0	
Cement	36.4	63.6	
Tiles	0.0	100.0	
Spouse Residence			0.51
With in the Village	51.9	48.1	
Other Village	33.3	66.4	
Town/ City	50.0	50.0	
Occupation			0.04
Farming	54.5	45.5	
Teacher	0.0	100.0	
Others	71.4	26.6	
External Exposure			0.17
None	69.2	30.8	
In another village in the District	50.0	50.0	
Village Outside District	57.1	42.9	
City	33.3	66.7	
Training in Soil and Water Conservation			0.00001
Yes	33.3	66.7	
No	85.7	14.3	
Land Tenure System			0.00001
Hired	87.5	12.5	
Owned	0.0	100.0	
Livestock on-farm			0.071
No	75.0	25.0	
Yes	50.0	50.0	

Table 1 b
Quantitative household characteristics for the Non-Adopter and Adopter Farm Households for the CSM-BGBD technologies (N= 84)

Parameter	Non-Adopters (Mean ± SE)	Adopters (Mean ± SE)	Overall (Mean ± SE)	Significance Level (t-test, p≤ 0.05)
Age of HHH (Years)	34.4 ± 1.9	46.2 ± 2.0	39.6 ± 1.5	0.0001
Age of Spouse (Years)	38.1 ± 4.7	50.6 ± 4.2	44.1 ± 3.2	0.52
Rooms in House (Counts)	1.9 ± 0.1	3.2 ± 0.2	2.5 ± 0.1	0.0001
HH Size (Counts)	5.0 ± 0.3	8.1 ± 0.6	6.4 ± 0.4	0.0001
Adults (60+ yrs) (Counts)	0.2 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	0.118
Females (18-59 yrs) (Counts)	1.0 ± 0.1	1.9 ± 0.2	1.4 ± 0.1	0.0001
Males (18-59 yrs) (Counts)	1.0 ± 0.1	1.4 ± 0.2	1.2 ± 0.1	0.058
Children (7-17 yrs) (Counts)	1.5 ± 0.2	3.4 ± 0.4	2.4 ± 0.3	0.0001
Children (Below 6 yrs) (Counts)	1.8 ± 0.2	1.9 ± 0.1	1.8 ± 0.1	0.646
HH Labor (Active members)	3.2 ± 0.2	6.4 ± 0.5	4.7 ± 0.3	0.0001
Farm Size (Acres)	1.35 ± 0.18	2.04 ± 0.26	1.63 ± 0.15	0.026

farming activities which other studies have found to be important in adoption of technology (13).The mean number of rooms in the house (proxy for wealth) was significantly (P≤ 0.0001) higher (3.2 ± 0.2) as compared to the non-adopters (1.9 ± 0.1). The household size, females in the house, children above 7 years, availability of household labor and farm size were significantly higher for adopters' households than non-adopter households: (P≤ 0.0001), (P≤ 0.0001), (P≤ 0.0001) (P≤ 0.0001) and (P≤ 0.026) respectively.

This study showed that where sufficient land was available, adoption of improved technologies occurred. Farmers with access to land and a productive labor force are going to adopt improved technologies. Other studies (8) have also indicated that ownership of land acts as an incentive for making investments in infrastructure on land and other soil conservation practices because there is no direct risk of loss of one's investments. With more labour smallholder households are able to plant more land to improve with the CSM-BGBD technologies. All adopters understandably reported increased labour requirements for establishment of the conservation technologies. However, age of spouse, adults above 60 years, adult males, and children below 6 years was not significantly different among the two categories.

2. Role of Social Capital in technology adoption

The most prominent SWC technologies practiced by farmers in the area are CSM-BGBD, early ploughing, cover crops, animal manure, crop residues, erosion control, fallowing, agroforestry and crop rotation. Adoption of these technologies was evaluated in view of the social capital (Table 2). In general, social capital (SC) significantly (P≤ 0.0001) influenced the adoption of soil and water conservation (SWC) technologies. There was a significant difference (P≤ 0.000) between the low and high social capital in practicing BGBD technologies. Among the respondents that were not practicing CSM-BGBD technologies, the majority (78.3%) were under low social capital, against the 21.7% under high social capital category. On the contrary, among the respondents that were practicing CSM-BGBD technologies, the majority (84.2%) were under high social capital, against the 15.8% under low social capital category. Early ploughing, application of manure, incorporation of crop residues, soil erosion control and land fallowing were significantly more frequently practiced by farmers belonging to the high social capital category as compared to those of the low social capital category (Table 2). Cover crop planting, agroforestry and crop rotation were not significantly different among the two categories of social capital.

Social capital facilitates social participation and has a positive relationship with the use of conservation practices, as reported before (1, 10). Among these groups where social capital is present, the farmers acquire informal farming education, which catalyses the process of information flow and leads the farmer to different pathways of getting information about a technology. The more information pathways the farmer has, the more the farmer intensifies adoption of soil and water conservation technology. Undeniably, studies of innovation, adoption and diffusion have long acknowledged information as a key variable, and its availability is typically found to correlate with adoption (7). Information becomes particularly essential as the level of intricacy of the conservation technology increases (13). However, contact alone will not promote adoption if information dissemination is ineffective, inaccurate or inappropriate (2). Although this study did not attempt to determine income levels for the households, it is highly probable that high social capital households had more disposable incomes that would allow them to make such investments. This is evidenced by their better quality of housing and

Table 2
Frequency of adoption of SWC technologies by the households as a function of social capital (SC) (N= 84)

Variables	Low SC (%)	High SC (%)	Significance (X^2, p≤ 0.05)
Practicing BGBD			0.000
No	78.3	21.7	
Yes	15.8	84.2	
Early Ploughing			0.001
Never	56.0	44.0	
Occasionally	50.0	50.0	
Regularly	23.1	76.9	
Cover Crops			0.052
Never	55.2	44.8	
Occasionally	50.0	50.0	
Regularly	16.7	83.3	
Apply Animal Manure			0.001
Never	59.4	40.6	
Occasionally	12.5	87.5	
Incorporate Crop Residues			0.020
Never	60.0	40.0	
Occasionally	55.6	44.4	
Regularly	25.0	75.0	
Soil Erosion Control			0.004
Never	68.4	31.6	
Occasionally	27.3	72.7	
Regularly	36.4	63.6	
Land Fallowing			0.048
Never	66.7	33.3	
Occasionally	38.9	61.1	
Regularly	37.5	62.5	
Agro forestry			0.067
Never	60.0	40.0	
Occasionally	30.8	69.2	
Regularly	50.0	50.0	
Crop Rotation			0.254
Never	66.7	33.3	
Occasionally	55.6	44.4	
Regularly	42.3	57.7	

engagement in other forms of employment.

The relationship between social capital and soil conservation is not a straightforward matter of investing in the rapid formation of self-sufficient community groups in order to accelerate adoption of soil conservation practices on farms (6). This could explain why cover crop planting, agroforestry and crop rotation were not significantly different among the two categories of social capital. Nevertheless, social capital has clearly contributed to changing farming practices in many studies (*ibid*). For instance, (6) showed that although membership in a local landcare group in the Philippines was not a major factor in technology adoption, the landcare approach as a whole (information sessions, training, cross-farm visits, follow-up by facilitators, farmer-to-farmer information exchange) created a valuable stock of bridging social capital, with significant benefits for long-term natural resource management.

Conclusions

This study has revealed that the most significant characteristics that distinguished SWC technologies adopters from non-adopters were training in soil and water conservation technologies, land ownership, quality of housing material or perceived wealth status, household location, other off-farm employments, gender of household head, age of household head, number of rooms in a house, availability of labor, farm size and social capital. This suggests that CSM-BGBD management strategies should consider uplifting these household attributes and strengthening social capital, where people create interconnectedness among themselves, to create multiple pathways for technology information flow to be able to reach a cross–section of primary stakeholders in the area. As quite a few other studies have indicated that the rate of adoption of SWC technologies is still low (12), consideration of these factors in the scaling out of the SWC is predicted to improve their adoption and thus intensify conservation of belowground biodiversity in Mabira forest reserve.

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