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Farmers' perceptions and attitudes towards introduced soil-fertility enhancing technologies in western Africa

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Abstract

Soil fertility enhancing technologies (SFETs) have been promoted in the West African Semi-Arid Tropics (WASAT) for many years with limited success. Using a qualitative approach of focus group discussions, long, open-ended interviews and observations from field visits, this paper explores with farmers their beliefs and rationales behind the adoption or non-adoption of SFETs. Farmers are knowledgeable about, and practise SFETs of rock phosphate application, crop residue and farm yard manure, chemical fertilizer and crop rotation to combat soil fertility decline. Their attitudes to and rationales behind adoption decisions are influenced by the availability and use policies of land and labour resources, food security concerns, perceived profitability, contribution to sustainability and access to information. Some of the factors are beyond farmers' control and require a broad and integrated effort from research, extension and government to promote the use of the SFETs in the region.

Introduction

Soil fertility depletion on smallholder farms has been cited as the fundamental biophysical root cause responsible for the declining per capita food production in Africa (Sanchez et al., 1996). Studies of soil nutrient balance across countries in Africa show evidence of widespread nutrient mining leading to severe nutrient deficiencies across ecological zones. Nutrient mining is estimated to average 660 kg of N, 90 kg of P and 450 kg of K per hectare during the last 30 years from about 200 million hectares of cultivated land in 38 African countries (Stoorvogel and Smaling, 1990). As a consequence of soil fertility depletion, farmers are often obliged to expand production to marginally unproductive lands as a survival strategy. This aggravates the land degradation problem, identified to be a serious threat to food production in the West African Semi Arid Tropics (WASAT) region (Bationo et al., 1995).

The concern for soil nutrient depletion and low soil fertility has led to the development of several soil fertility enhancing technologies (SFETs) by a number of national and international research institutions and development agencies in the WASAT (Bationo et al., 1995). However, these technologies have not been adopted to any appreciable extent by farmers. The level of fertilizer use, for example, remains low, estimated at less than 10 kg of nutrients ha^{-1} in Africa, and even lower in the dry land areas because of rainfall uncertainties (Vlek, 1990). Farmers have also been observed to react to the low soil fertility problem by making adjustments to introduced SFETs, or by using traditional practices to combat the decline in fertility. The traditional practices include a judicious use of livestock in cropping systems, where livestock provides traction power for tillage, manure for organic matter and cash income for the purchase of mineral fertilizers. The manure is often obtained through symbiotic arrangements between farmers and herdsmen where animals are corralled on farmers' fields in exchange for food. In the allocation of scarce manure and inorganic fertilizers, farmers use a maximizing strategy based on a system of triage where fields judged to benefit most would receive the maximum inputs. According to Prudencio, 1983 the allocation usually follows concentric cultivation patterns, going from more inputs to fields close to the homestead to less inputs in far off fields.

Studies on the adoption of soil fertility enhancing technologies (SFETs) in the WASAT region have cited infrastructural constraints, lack of access to inputs, lack of information, as well as high costs as the major reasons for the non-adoption of SFETs (Adesina, 1996; IFDC, 1990). These studies have largely adopted the traditional quantitative and economic analyses, and have not addressed important social and cultural factors underlying adoption behaviour adequately. The present study complements these and other adoption studies by investigating the subjective and cultural processes which underlie farmers' practices and attitudes towards introduced SFETs in the region. The objective is to explore with farmers, their rationales for adoption or non-adoption of selected SFETs developed and disseminated in some regions of Burkina Faso, Mali and Niger. The study uses a qualitative method based on farmer group discussions and open-ended questions to elicit from farmers their views on the SFETs and what limits the implementation of those practices. These information are essential in better understanding the beliefs and attitudes held by farmers towards introduced soil fertility enhancing technologies. They will also guide research and extension personnel in refining their research and development agenda to respond to the felt needs of farmers.

Materials and methods

Study area

The study was carried out in three countries in the WASAT region: Burkina Faso, Mali and Niger (Figure 1). The survey zone covered areas within the Sahelo–Sudanian zone with annual rainfall between 350–600 mm, the Sudanian zone (600–800 mm), and the Sudano–Guinean zone (above 800 mm). The study area is characterized by a short uni-modal rainfall pattern which lasts about 2 to 6 months, and a dry season. The rainy season occurs between the months of May and October. As one moves along the north–south transect, there is a decrease in rainfall variability and an increase in the amount of total rainfall. However, the WASAT has witnessed a secular decline in rainfall over the last 20 years with the isohyets moving farther southwards. Agricultural production is risky due to the highly variable rainfall. The cropping system varies with the ecological zone with a larger variety of crops grown in the Sudano–Guinean zone as compared to the sahelian zone (Table 1).

Methodology

The study used a qualitative approach, employed widely to better understand the beliefs and attitudes held by farmers towards different technologies (Lockie et al., 1995; Morgan, 1990; McCraken, 1990; Ward et al., 1991) to investigate farmers' perception, attitude and utilization of soil fertility enhancing technologies. The approach is based on the premise that farmers' subjective assessments of agricultural technologies influence their adoption behavior (Adesina and Baidu-Forson, 1995; Nowak, 1992). Through the qualitative approach, participants have the opportunity to raise issues and questions which may not have otherwise been considered by quantitative research instruments.

A non-probability sampling procedure based on theoretical or judgmental sampling theory of Jorgensen (1989), was used to select the study sample. The procedure allows the researcher to make selection decisions based on 'constraints such as opportunity, personal interest, resources, and most important, the problem to be investigated' (Jorgensen, 1989 p. 50). The sample villages selected from Mali, Burkina Faso and Niger are shown in Figure 2 while the breakdown of the 117 farmers interviewed, including the periods of interview at each location is summarized in Table 2. The choice of sample farmers was based on criteria including location of the farmer (zone of production, distance from principal city, and willingness to participate in the study as members of focus discussion groups or in interviews). The study sites were classified into a cotton producing zone (CPZ) and a non-cotton producing zone (NCPZ). The CPZ included Sikasso and Koutiala regions of Mali, and the Bobo Dioulasso region of Burkina Faso. The NCPZ on the other hand, included the Yoko/Kilsi and Manga/Tiougou regions of Burkina Faso and Banizoumbou, Fabirdji, Carabedji, Tanda, Goberi, and Hamdelaye/Falanke regions of Niger. The classifica-

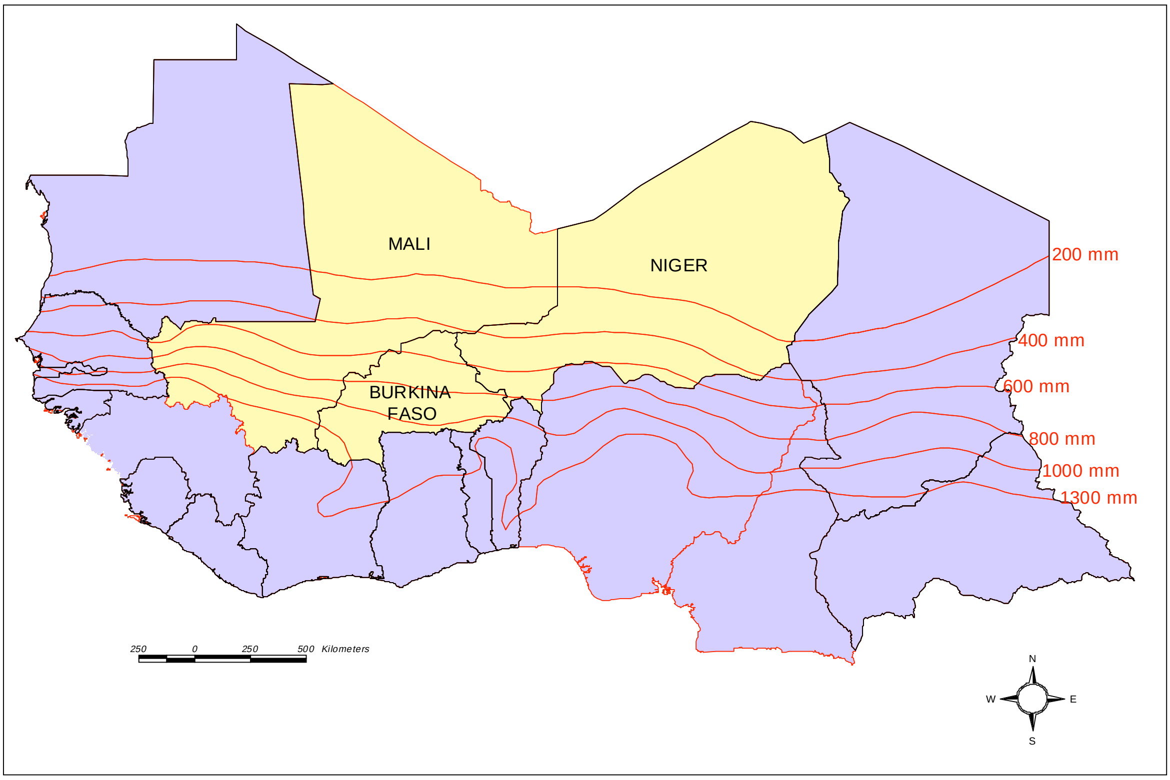

Figure 1. Map of West Africa showing the study countries of Burkina Faso, Mali and Niger.

Table 1. Characteristics of the major agroecological zones in the West African Semi-arid Tropics (WASAT)

Zone	Rainfall (mm)[a]	% area in WASAT[b]	% population in WASAT	Major cropping system	Population density	Crop technology development potential
Sudano–Guinean	800–1100	24	6	Highly diversified, high-input system; cotton, maize, groundnut, sorghum, millet, vegetables, chippies, rice and livestock	Low; historically high disease risk but less now	High
Sudanian	600–800	21	59	Sorghum, pearl millet, maize, chippies, vegetables and some cotton[c]	High	Moderate
Sahelo–Sudanian	350–600	30	19	Same as sudanian but moving farther north; pearl millet-cowpea intercropping, some sorghum nomadic grazing	High in southern section but declining farther north	Lower than for sudanian sorghum system; low for millet-cowpea system
Sahelian	<350	24	16	Transhumance or traditional nomad centre; subsistence pearl millet and cowpeas	Low	Minimal, except around water

[a] With 90% probability.
[b] Estimates of the cultivable area in the four zones are Sudano-Guinean, 42%, sudanian, 37%, Sahelo–Sudanian, 30% and Sahelian, 29%.
[c] The sorghum system predominates in heavier soils; millet in the lighter, sandy soils and a mix of sorghum and millet in the intermediate soils.

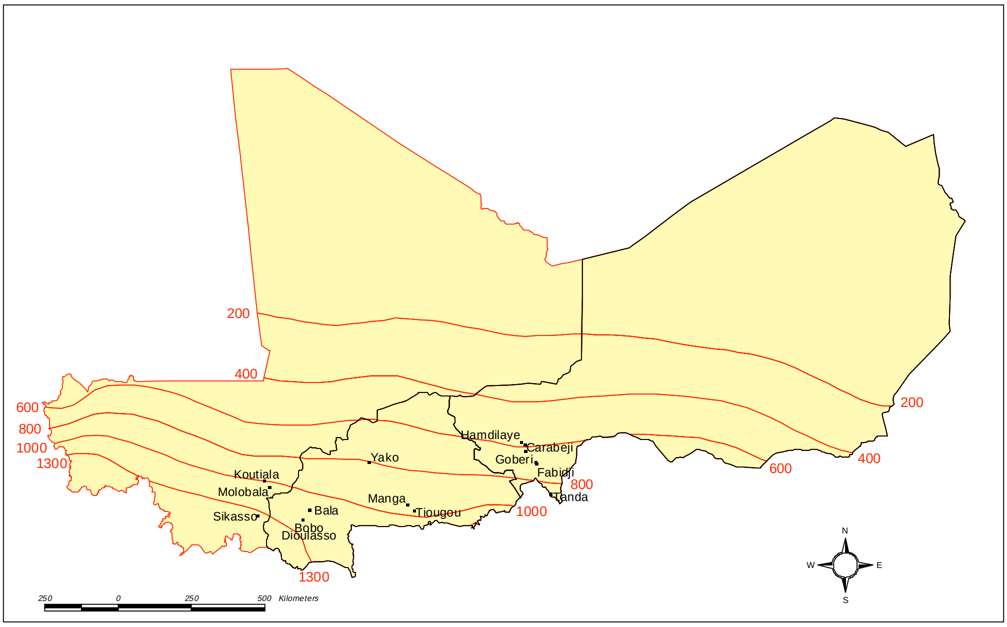

Figure 2. Map of Burkina Faso, Mali and Niger showing study villages.

Table 2. Study sample and farmer interview schedule

Zone	Country	Principal city	Village	Distance from prin. city	Date of interview	No of Focus Group Interviews	No of Long Interviews	No of fields visited	Total no. of farmers interviewed
CPZ	Mali	Sikasso	Lofigue	80 km	29/7/96	1	1	14	7
CPZ	Mali	Sikasso	Norayadougou	60 km	30/7/96	2	-	6	4
CPZ	Mali	Sikasso	Gongasso	65 km	30/7/96	1	1	2	5
CPZ	Mali	Koutiala	Molobala	75 km	5/8/96	1	1	4	11
CPZ	Mali	Koutiala	Autour de San	75 km	5/8/96	1	-	3	7
NCPZ	Niger	Niamey	Banizoumbou	80 km	9/8/96	2	-	6	16
NCPZ	Niger	Niamey	Fabirdji	130 km	10/8/96	1	-	2	8
NCPZ	Niger	Niamey	Carabedji	120 km	10/8/96	2	-	4	22
NCPZ	Niger	Niamey	Tanda	300 km	11/8/96	1	1	5	3
NCPZ	Niger	Niamey	Goberi	120 km	14/8/96	2	3	3	10
NCPZ	Niger	Niamey	Hamdelaye Falanke	40 km	16/8/96	1	1	1	5
NCPZ	Burkina Faso	Ouagadougou	Yako/Kilsi	150 km	20/8/96	1	-	2	5
NCPZ	Burkina Faso	Ouagadougou	Manga/ Tiougou	150 km	21/8/96	1	1	2	11
CPZ	Burkina Faso	Bobo-Dioulasso	Bala	60 km	24/8/96	-	3	3	3
Total									117

CPZ = Cotton producing zone.
NCPZ = Non cotton producing zone.

tion of the study area into these two zones arose from the basic differences between them. CPZ farmers, as opposed to NCPZ farmers have relatively easy access to credit, fertilizer, other inputs and are blessed with basic infrastructure that are likely to have positive influence on adoption decisions of the SFETs.

Data were collected from all the 117 farmers in the sample using three different techniques: i) focus group interviews involving 48 farmers; ii) long qualitative interviews with 12 farmers; and iii) guided field visits involving 57 farmers. The focus groups, which were made up of members representative of key sectors of the population, allowed a free exchange of views on SFETs with the scientist acting as a facilitator. The long qualitative interviews which involved farmers, extension staff and researchers gave the interviewer the opportunity to share the informants experiences and points of view on different issues related to the SFETs. The field visits provided the farmer the opportunity to show and explain aspects that they felt strongly about. These visits also allowed the interviewer to observe phenomena that could not have been transmitted just by explanation. To the extent possible, the interviews were recorded using a portable audio cassette recorder and later on transcribed. Data analysis was done using grounded theory and procedures developed by Strauss and Corbin (1990). From the analysis, a number of emerging themes that identify and regroup similar ideas on selected aspects of the SFET adoption investigations was developed and discussed. Where appropriate, a qualitative ethnographic summary that involved quotations from the group and individual interviews was used to illustrate and support points of view expressed by the informants.

Results and discussion

Four general types of SFETs emerged from the discussions, interviews and field visits as the most frequently used soil fertility enhancing technologies in the region. They are: i) application of naturally occurring rock phosphate (RP) as soil amendments; ii) use of crop residues (CR) and farm-yard manure (FYM); iii) mineral fertilization; and iv) intercropping and crop rotation. Their broad descriptions and recommended doses are summarized in Table 3 while in Tables 4 and 5, the rationales behind the adoption and non-adoption of the SFETs are presented, respectively.

Soil amendments – Application of phosphate rock (PR)

Since phosphorus has been shown to be one of the most limiting nutrients in the WASAT, research efforts in the last decade were focused on soil amendments based on the use of readily available, naturally occurring phosphate rock deposits found in most of West Africa (IFDC, 1990; Steiner, 1991; Sedogo et al., 1991). Research results have shown that their direct application is a viable alternative to the more expensive, soluble imported phosphorous fertilizers (IFDC, 1990; Bationo et al., 1995). This naturally occurring P in the form of phosphate rock, with recommended at doses of 400 kg ha^{-1} in the first year and 100 kg ha^{-1} in subsequent years, was introduced in the region as a source of soil amendment (Table 3). A major constraint to the adoption of the natural PR technology is the complexity of the phosphorous dynamics. Its sorption (fixation) and desorption (release) processes are long, and the effects are not immediately seen by farmers as they do when they apply phosphorus in a more direct form. In addition, farmers lack access to the PR technology, and when they have access, the product is packaged and presented in a powder form that is cumbersome and inconvenient for farmers to use.

Crop residues (CRs) and farmyard manure (FYM)

Crop residue and farm yard manure technologies have been extensively introduced to farmers in the region. They serve both as soil amendments and as sources of nutrients. Bationo et al. (1996) and Berger (1990) reported that crop residue (CR) application of 2 tons ha^{-1} as mulch reduced the amount of soil flux on pearl millet seedlings. Field experiments on mulching have shown that optimum levels of CR to be applied in the Sahelian zone was 2 tons ha^{-1}ICRISAT (1993). Only few farmers in the region use crop residue as mulch. This is because limited amounts are available and farmers usually have problems incorporating residue during land preparation. After using CR for animal feed, as building material and for fuelwood what is left on the fields is usually burnt during land preparation. For farmers to be able to apply the recommended levels of CR, stover production at farmer level has to be increased significantly. The constraints to FYM use include problems with the supply of high quality manure in adequate quantities recommended by research. To overcome this constraint, scientists have introduced the production of high quality FYMs by the addition

Table 3. Soil Fertility Enhancing Technologies in use by farmers in the 350 mm to 1300 mm rainfall zones of Burkina Faso, Mali and Niger

Type of SFET in use	Description/recommended doses
Soil amendments:	
Rock phosphate: (Naturally occurring)	Direct application of crude RP. In general 400 kg RP per ha per yr. for the first year and 100 kg RP per ha per yr. for subsequent years
Partially acidulated	Direct application of partially acidulated RP. In general 400 kg RP per ha per yr. for the first year and 100 kg RP per ha per yr. for subsequent years
Dolomie de TIARA	Direct application at a rate of 1000 to 1500 kg/ha
Crop residues & farmyard manure	
Improved pen	Use material from improved pen and add crop residue
Integrated with phosphate	Manure plus straw plus rock phosphate. 1 bag of RP per 1.7 ton of wet manure/compost i.e. 1 bag of RP/7500 kg of hay equivalent to 10 donkey carts of hay
Inoculated rice hay	Apply manure + hay + inoculum
Composting	Using household refuse + other weeds and organic matter from crop residue (e.g. fresh corn husk, grain husk) from around the home (Contains approximately 1.0 - 0.4 - 1.8 NPK)
Crop residue	(a) Application of CR as mulch 2 t/ha
	(b) Incorporating straw in the soil
Chemical fertilizers	Different types of complex fertilizers made up of Nitrogen,
Complex fertilizer	phosphorus & potassium and in some cases S(Sulphur) and B(Boron)
For cotton	14 - 22 - 12 (NPK) plus 5 to 7 S and 1 B
New formulation	18 - 9 - 18 (NPK)
For Cereals	15 - 15 - 15 (NPK)
New formulation	18 - 9 - 18 (NPK)
Intercropping/rotation	Cereals intercropped or rotated with legumes such as cowpeas, groundnuts and Stylosanthes
Cereal/legume rotations	

Source: Interviews with research and extension personnel as well as declarations of farmers during field visits.

of naturally occurring phosphate rock during its preparation in improved pens in Burkina Faso and Mali. Labour availability also constraints the use of both CRs and FYMs in the study area.

Mineral fertilizer application

Different rates of fertilizer application have been developed and proposed to farmers in the region. The most common fertilizers are complex fertilizers for cotton and for cereals. All the farmers involved in the study had at one time or another used mineral fertilizers. Of the 117 farmers interviewed, 75 had fertilized their fields in the preceding season. In the cotton producing areas, all the farmers interviewed had applied chemical fertilizer on cotton and only 27% had fertilized other fields in addition to cotton. On the contrary, of the farmers interviewed in the non cotton producing areas, only 35% had used fertilizers on their fields and 65% used no chemical fertilizer. Farmers in the CPZ usually use the complex cotton fertilizer (14-22-12, NPK) while those in the NCPZ depend mainly on the cereal complex fertilizer (15-15-15, NPK). Recent studies have however shown that the prolonged use of mineral fertilizer alone has resulted into decreasing crop yields due to soil acidification and loss of organic matter (Bationo et al., 1995; Sedogo, 1993). As a result, recommendations now call for the use of mineral fertilizers in combination with organic fertilizers. The main constraints cited by the farmers for the non-adoption of chemical fertilizers at the recommended doses included the lack of access, high costs and lack of credit facilities.

Intercropping and crop rotation

The group discussions revealed that intercropping and crop rotations with legumes have been used exten-

Table 4. Farmers' rationale(s) for adoption of selected SFETs

Type of SFET	Rationale(s) for adoption	Examples ofsupporting ethnographic quote(s)
Soil amendments: Rock Phosphate Technology	1. Provided free of charge 2. Enables us to have access to credit and other inputs for cotton production	
Crop residues & farmyard manure: Crop Residue Technology	1. Enough residue could be produced to cover portions of the fields. 2. Perceived as conserving the soil structure 3. Ease of rapid decomposition	"There is very high termite activity in the region. This speeds up the break down of the left over stems and millet stumps" "It is because of these crop residue in my fields that I can conserve my soil structure. This way I could guarantee my self viable crops for the next 2 to 3 years".
Farm Yard Manure Technology	1. Cheaper than mineral fertilizer 2. Arrangements for manure supply can easily be made with herdsmen in exchange for forage (CR) and a meal 3. Resources can easily be pooled to apply FYM	"I prefer using manure because it costs less than fertilizer. I make arrangements with Peulh herdsmen and they camp their herds on my fields". " During the period of application, we put our carts together and carry the manure together. We do one field at a time"
Chemical fertilizers: Complex Fertilizer Technology	1. Ease of use (direct application) 2. Immediate and visible effect during crop season as opposed to rock phosphates 3. Provides residual effect for subsequent seasons	"I prefer complex fertilizer because not only is it easy to use and you see its effect almost immediately, its residual effect on the following year's crop is wonderful". "I prefer using the NPK 15-15-15 because of its residual effect whereas if it were the Urea it is good for only one year".
Intercropping/rotation: Crop Rotation Technology	1. Age-old practice that fits into cropping pattern	

sively to restore fertility in the study area. Legumes increase soil fertility through their nitrogen-fixing capacity. Because of this property, improved cereal-legumes and cotton-legumes rotations have been proposed to farmers in the region as an inexpensive way to improve soil fertility and production (ESPGRN, 1994; Bationo et al., 1996). In a trial at Tara in Niger, Bationo et al. (1995) concluded that at an application rate of 45 kg N ha^{-1}, yields of pearl millet for continuous monoculture were lower than when N was applied and the cereal crop was followed by groundnut in a rotation. Other on-farm trials conducted at Tara (Niger), Sikasso and N'tarla (Mali) stations reported that the yields of maize planted in *Stylosanthes* fodder banks nearly doubled those on natural fallow (Bationo et al., 1995; ESPGRN, 1994).

Attitudes, perceptions and rationales behind SFETs adoption decisions

It is not always clear to the outsider why farmers adopt some technologies or practices over others. Sometimes, when there is inadequate understanding of the rationales behind their decisions farmers behaviour and beliefs may appear to the outsider as irrational, contradictory and against their interests. During the course of the group discussions, interviews and field visits, the rationales behind the decisions to adopt or not to adopt the SFETs were solicited. It revealed that farmers' attitudes and rationales behind adoption or non-adoption decisions of SFETs are influenced by the availability and use policies of land and labour resources, food security concerns, perceived profitability and contribution to sustainable production and access to SFET information.

Availability and use policies of land and labour resources

Farmers, particularly those in the CPZ have identified population pressure as a major factor influencing the re-distribution and use policies of farm land. The re-distribution has resulted in land fragmentation over large areas making it difficult to transport bulky crop residue, rock phosphate and farm yard manure to distant fields. In addition, farm land has more recently been rented to migrants to the villages, and family members only have had user rights to land. Since

Table 5. Farmers' rationale(s) for non-adoption of selected SFETs

Type of SFET	Rationale(s) for non-adoption	Examples of supporting ethnographic quote(s)
Soil amendments: Rock Phosphate Technology	1. The form of the RP is cumbersome and wasteful to use 2. Its effect is not immediately seen.	"the CMDT had in fact used a very bad way of extending it. They have in fact forced farmers to take PNT – because of the whole credit system. So farmers who were agreeing to plant a certain area of cotton, got PNT and at the end of the year it was deducted from their accounts. And that has got a lot of farmers frustrated for which PNT has not really got a good extension radii".
Crop residue & farmyard manure: Crop Residue Technology	1. Not enough (supply problem) 2. Competes with animals, considered as of higher value 3. Competes as building materials and as fuelwood 4. Transportation problems 5. Labour demanding	"I do not have enough residue to cover the whole field. Besides it involves a lot, of work since after harvest we collect the CR to the village where we use the leaves to feed the animals then transport it back to the fields and spread them". "I do not have enough animals to make any reasonable quantity of manure for my fields. So I put crop residue on the field. It will decompose and fertilize the soil during the next 2 to 3 years. I rotate the area that I apply it every year".
Farm Yard Manure Technology	1. Problems of quantity; not enough production 2. Problems of labour (young men migrate out of the villages) 3. Transportation problems	"If one has no means of transporting the manure to distant fields he is forced to produce only enough for the fields near the home. These fields are not as bad as those far from the home as we dump household refuse on these home gardens and when the women separate millet, the husk thrown around these fields".
Chemical fertilizers: Complex (mineral) Fertilizer Technology	1. Non availability – scarcity in market 2. Lack of access to credit to purchase fertilizer 3. Under-dosage (not effective)	"This year I have not used fertilizer because I could not get any to buy. I even gave money to a dealer who was going to Nigeria but to this day, I still did not get any".

migrants perceived their stay as temporary, and family members had no secured ownership rights to the land they farm, there were no incentives to long-term investments in SFETs.

Availability of labor was cited as a major limiting factor to adoption of SFETs. Most of the labour was provided by family members and the recent exodus of the youth from the rural areas have affected the extent to which these SFETs are adopted. Farmers indicated that they had to reduce the number or size of their fields in order to adjust to the labour constraint. Others said that due to labour shortage they have not been able to adopt SFETs that require extensive labour investments.

These constraints have often led farmers to continually adapt SFETs to suit their limited resources. Recommended fertilizer doses were for example modified and adapted to fit within the farmers' financial constraints. Since they could not afford the full recommended doses, some farmers adapted it by applying small quantities in pockets rather than by broadcasting. Other adaptations include applying FYM in pockets and rotating the fields for the benefit to be spread over time. As one farmer suggested, summarizing the feelings of the group:

> "With the limited amounts of manure and compost that we can generate, we cannot fertilize the entire field. So we rotate the application of the manure. We start with the areas that need it the most and rotate application each year until the whole field has been covered".

During discussions with researchers and extension personnel it was noted that farmers' adaptations of the recommended doses (deviations from research and extension recommendations) have not adversely affected production. In many cases, they have resulted in reasonable yield increases. The adaptations have therefore become the basis of further research investigations leading to the revision of the recommended doses.

Food security concerns

A major concern of the farmers is that of ensuring a minimum level of food production to meet the family's needs. This leads them to adopt only the technologies that they consider as having the minimum risk and highest payoff. The strategy includes adopting SFETs on fields near the homestead where they benefit from the maximum amount of care. A farmer explaining the importance of the homestead fields in its household's food security strategy declared:

> "This field is very important to me. Since it is near the home it gets household manure and is where we first harvest while waiting for the rest of the fields which are further away to mature. I use local varieties here and the improved varieties in the far away fields. This is because if we plant improved varieties here on these good soils they ripen before other crops in the area. So birds and animals eat and destroy it as there is no other food to eat. This robs the family of its food needs".

Perceived profitability and sustainability of production

It emerged from the discussions that CPZ farmers use cash income from cotton production for the purchase of inputs, mainly chemical fertilizer. The decision to adopt chemical fertilizers as a SFET in the cotton producing zone is therefore largely a function of cash availability and perceived profitability of cotton relative to other crops. Other factors influencing profitability in the CPZ is the enabling environment of adequate and reliable market outlets for inputs and products, access to credit, presence of extension personnel and ready access to information on SFETs. The perceived profitability explain why farmers are willing to invest more in the SFETs in the cotton producing zone than in the non-cotton producing zone.

Besides profitability, farmers are also concerned about sustainability of production on their fields. They pointed out that they tend to weigh the SFETs according to their sustainability criteria: maintaining productivity over time, reducing instability or fluctuation, and increasing resistance of the system to external shocks.

Access to information of the SFETs

Farmer-to-farmer transfer of SFETs play a very important role in the technology transfer. The majority of farmers claimed they took decisions to adopt the technologies based on information on how they fared in their neighbour's fields. Farmers who saw how new technologies performed on their neighbours' fields experimented and later adopted them on their own fields. Examples of this could be seen in the following comments made by farmers at various instances during the interviews. In the Carabeji village, during a focus group discussion a farmer said:

> "As we told you, we visit our neighbours' fields to see the different things they practice with the research agents. And sometimes the agents recommended certain things to us. Hence it entails a direct observation of the technique on the field with trials e.g. we go from time to time to his field to see the nitrogen fertilizer trials".

Another farmer, this time in Goberi village who was involved in on-farm research activities remarked:

> "Many farmers come and look and appreciate my fields. They see how in certain sections the sorghum and millet are doing very well. These are sections that had cowpeas the previous year. I hear others talk about my fields in the village. I have even seen one of them who is now practicing legume rotation on his field".

Beside observing other farmers' practices, the farmers also expressed concern about the lack of information from research and extension on the full aspects of the SFETs that they have helped introduce into the area. The need for information was in the areas of information on technology availability and access, their costs and benefits as well as their impact on the environment.

Farmers rationales behind adoption or non-adoption of SFETs

The rationales behind SFETs adoption and non-adoption decisions are summarized in Tables 4 and 5, respectively. It appeared that farmers' main rationales behind the non-adoption of rock phosphate was that its effect on production was not immediately obvious compared with chemical fertilizers. This was due to the fact that the rock phosphate technology was disseminated erroneously as fertilizer instead of as soil amendments. Farmers who adopted RP technology in the cotton zone of Mali claimed they did so because it was distributed free of charge and besides, the acceptance of PR permitted them to have access to other inputs.

Farmers who adopted crop residues claimed they perceive its benefits in improving the soil structure through termite activity and that they were relatively easy to produce and manage. The rationale behind the non-adoption of crop residue is that it is perceived more as animal feed and for building materials than as organic material. Chemical fertilizers on the other hand are largely perceived as plant nutrients that provide immediate benefits and adopters claim they would use them in the recommended quantities if they were readily available, within their financial resources or could have access to credit.

Summary and conclusion

Farmers in the study area are aware of the declining soil fertility problem and the resulting declines in food production. They use several methods to restore soil fertility of which the main ones are application of naturally occurring rock phosphate (RP) as soil amendments, use of crop residues (CR) and farm-yard manure (FYM), mineral fertilization and intercropping and crop rotation. The adoption decisions of the technologies are influenced by the availability and use policies of land and labour resources, food security concerns, perceived profitability and contribution to sustainable production and access to information. When farmers modify recommended SFET practices, they do so in order to adapt them to their often limited land, labour and financial resource constraints.

Despite the many constraints and concerns, most farmers identified positive benefits on the limited areas on which they had been able to implement the different SFETs. Many of the concerns expressed were clearly outside the sphere of research and extension, and require positive involvement of government and local community leaders. Farmers for example are not willing to risk investing in producing more than they can consume unless there are market outlets to absorb the surplus production. Some also feel they could make long term investments in SFETs if they are assured of reliable market outlets. It is thus necessary for government to provide the basic infrastructure for farmers to have easier access to input and product markets. Similarly, the lack of property rights, especially for young farmers and women, is also a major disincentive for investments in long term soil fertility improvement. It is important for village and community leaders to review their land re-distribution and use policies in order to remove the constraints to long term investments in SFETs.

There is also a great deal research and extension can do to assist farmers. These are in the areas of re-evaluating and refining SFET recommendations in the light of the farmers' limited resources. Another important area is in the provision of adequate information on technology availability and access, costs and benefits and their effects on the environment to help the farmers make informed decisions.

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