Sustainable soil fertility management in Benin: learning from farmers

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Abstract

The perception of farmers from the Atacora and Savè regions of Benin was studied about the causes and consequences of land degradation and corrective actions for sustaining soil fertility. Research methods in this diagnostic study included group discussions, using non-standardized unstructured interviews and participant observations. Farmland degradation leading to declining yields, and land tenure arrangements were identified as the main constraints on the sustainability of agriculture. In both regions the farmers stated that climatic changes (less and more irregular rainfall), run off, erosion, and overexploitation of farmlands caused land degradation. Soil fertility status was assessed on the basis of dicotyledonous weeds, soil texture and colour, and soil fauna (earthworm casting activity). Farmers have adapted their cropping systems to the local environment by developing traditional and new strategies and activities that could contribute to maintain or enhance crop productivity. These strategies include animal manure, inorganic fertilizer, crop rotation, a five-year fallow, extensive cropping systems with cassava or *egusi* melon, and emigration. Land tenure arrangements between landlords and migrants affect strategies that can be applied to maintain soil fertility. The importance of building mutual trust and the need to experiment with different land tenure arrangements are indicated. A framework for interactive research where knowledge is collectively generated is proposed in order to test the effectiveness and applicability of some of these local innovations not yet well understood by conventional science.

Additional keywords: soil degradation, indigenous knowledge, land tenure arrangement, social dilemma

Introduction

Worldwide, soil fertility decline has become a major concern of policy makers (Gray & Moran, 2003). The Neo-Malthusian assumption is that soil fertility decline is an inevitable consequence of population growth and mismanagement of land resources. However, an alternative approach from Neo-Boserupians claims that population growth could, under certain conditions, result in less erosion, more forest cover and increased soil fertility (Tiffen & Mortimore, 1994; Fairhead & Leach, 1995; Leach & Fairhead, 2000a). Apparently, the nature and extent of land degradation are imperfectly understood. Many technological and institutional innovations that can solve soil fertility degradation have been developed and yet, these innovations do not generally appear to be successful (Biot *et al.*, 1995; Floquet, 1998; Versteeg *et al.*, 1998; Alohou & Hounyovi, 1999; Wennink *et al.*, 2000; Douthwaite *et al.*, 2002). The local people often reject proposed technologies that have been imposed from outside and delivered top-down. The main reasons are a lack of fit between the proposed techniques and the local farming systems and farmers' livelihood strategies, limited availability and accessibility of external inputs, lack of market access, inappropriate land tenure conditions and finally lack of participation by land-users in designing and implementing technologies. Instead, farmers adopt their own individual and collective approaches that have in the past resulted in sustainable livelihood practices (Biot *et al.*, 1995). The challenge is to listen to and learn from farmers' own knowledge. There is ample room for approaches that transcend the analytical dichotomy between scientific and indigenous knowledge in relation to West African farming systems and for a convergence of formal and informal sciences (Richards, 1985; Leach & Fairhead, 2000b).

Farmers' soil knowledge offers a different set of temporal and spatial scales with regard to land use, which has important implications for sustainable agriculture (Brouwers, 1993; Sandor & Furbee, 1996). Local people have significant knowledge of soils and environments, acquired by experiences that have been tested by many generations living close to the land (WinklerPrins, 2003). Understanding farmers' indigenous knowledge and practices on soil fertility management means understanding local realities, which is crucial for the potential success or failure of any type of agriculturally-based development (WinklerPrins, 2003).

Farmers in the Atacora region of Benin are facing soil degradation (Adegbidi *et al.*, 1999; Mulder, 2000). Nutrients are lost due to the relatively hilly relief with slopes of about 15%. Agricultural intensification reduces soil organic matter, which leads to nutrient depletion thus threatening the sustainability of the farming systems (Saïdou *et al.*, 2003). In contrast, farmlands in the Savè region are more fertile and the cropping systems are still based on shifting cultivation. Nowadays there is a large influx of migrants (Edja, 1996; Anon., 2000; Mulder, 2000) from Atacora and the southern regions of the country where farmers are running away from soil degradation and nutrient depletion. While migration may be a novel social strategy that releases pressure on the land in one area, it may simultaneously increase pressure on the land and on social relationships (insecure land tenure) elsewhere. Insecure land tenure encourages soil-mining practices, which reduce the long-term productivity of the land. Not much is known about the specific details of farmers' knowledge in relation to key soil fertility management decisions.

The present diagnostic study is an entry point for the Convergence of Sciences programme (Röling *et al.*, 2004) experimenting with an interactive approach with farmers to tackle the soil fertility depletion problem. In this process, the development of a systematic bottom-up approach for innovation development and dissemination is one of the main issues. It follows on the technographic study (Richards, 2001) carried out from October to December 2001 in relation to cotton, sorghum and cowpea (Kossou *et al.*, 2004).

The aim of this diagnostic study is to describe and compare the Atacora and Savè regions in Benin in terms of (1) farmers' perception and knowledge about causes and consequences of land degradation, (2) farmers' criteria and approaches for soil classification and differentiation, (3) corrective actions for sustaining soil fertility management based on interactive research and farmer experimentation, and (4) a framework for understanding the social side of the land (tenure arrangements). At the end, the paper takes a reflexive stance, when it looks back at the diagnostic study and critically looks at the choices that have been made to arrive at the next phase of the research.

Materials and methods

The study area

The diagnostic study was carried out in two regions, Atacora and Savè.

Atacora

The Atacora region is dominated by the Atacora mountains, with altitudes varying from 400 m in the south to 650 m in the north (Faure, 1977). The region is close to the Sahelian zone. The climate is tropical, of the Guinea-Sudan type characterized by strongly contrasting seasons with a single rainy season from mid-April to mid-October and a dry season from November to March. The annual precipitation varies from 1000 to 1300 mm (Natitingou weather station). The average annual rainfall over the last 30 years was somewhat lower than the long-term average. Farmers claim that the climate is changing (less and more irregular rainfall). But the available data do not permit to determine whether this is true or whether agricultural intensification leads to loss of soil organic matter and a lower water-holding capacity, which have similar effects on agricultural yields as a drier climate. The average yearly temperature is about 26.5 °C. Most of the soils are tropical ferruginous soils (Faure, 1977) classified by FAO as Ferric Lixisols (Anon., 1990). The soils are limited in depth by gravel and lateritic formations and are suffering from crusting and compaction. With few exceptions, the soils have a low inherent fertility. The vegetation is open savannah. There are large differences in population density within the area (9 inhabitants km^{-2} in Bassila in the south against 49 and 62 inhabitants km^{-2} in Boukoumbé and Kobli, respectively) (Anon., 1994). The population consists largely of farmers (92%). Most of the indigenous population belongs to the *Ditammari* ethnic group. Other major ethnic groups are the *Yom* (in the south), the *Berba* and *Waama* (in the central zone), the *Bariba* (in the north-east) and the *Peulh* (herdsmen), who are scattered over the entire region. As a consequence of the relatively low inherent soil fertility and the rather high population pressure, the region experiences a pressure on the land especially in the hilly zones. So the Atacora region is an emigration area, with mainly younger people leaving for the Savè region.

Savè

The Savè region too is characterized by a Guinea-Sudan climate with a unimodal rainfall distribution. The rainy season is from April to October. The average annual rainfall over the last 30 years is about 1100 mm (Savè weather station). The average yearly temperature is about 27.5 °C with little variation from year to year. Like in the Atacora region, the area is essentially dominated by tropical ferruginous soils (Dubroeucq, 1977), originally from Precambrian crystalline rocks (granite and gneiss). In contrast with the Atacora region, the soils are deep, without laterite, and often have a somewhat higher inherent fertility. Land is not yet a limiting factor. The natural vegetation is of the mosaic sub-humid savannah type. The population density is comparable to the one of Atacora, with about 22 inhabitants km^{-2} (Anon., 1994). The indigenous population is composed of the *Tchabè* and the *Peulh*. Since 1975 there has been an influx in the region of migrants from Atacora and the Abomey Plateau. This has led to the emergence of new communities in the area such as the *Ditammari*, *Yom* and *Waama* (from Atacora), the *Fon* (from Abomey plateau) and the *Idatcha* from Dassa Zoumè and Glazoué.

Research activities

The diagnostic study was carried out during the cropping season (June–November) of 2002. It comprised two phases, an exploratory survey and an in-depth survey (Figure 1). The exploratory survey was carried out in seven disticts: Boukoumbé, Matéri, Ouaké and Kouandé in north-west Benin (Atacora region), N'dali and Tchaourou in mid-east Benin (the South Borgou region) and Savè in the south-eastern of Benin (Savè region). They were selected in close collaboration with the various actors that are active in these regions (extension service CARDER, NGOs and R&D). In total, 15 villages (Figure 2) were studied. The introduction of the researcher in each village was facilitated by the local extension service (CARDER) and the farmer organization (Groupement Villageois – GV). The selection was based on accessibility, distance to the major nearby town, relevance of land degradation problems, and land tenure. The in-depth survey was subsequently carried out in seven villages: Tchato, Tchanhoun-Cossi, Gnalo, Madjatom, Boubouhou, Ouoghi central and Ouoghi gare. Their selection was based on accessibility, farmer availability and interest in the project (judged from their participation in the group meetings and the critical dialogues engaged during each meeting), relevance of land degradation problems and related soil fertility management strategies adopted, socio-economic and cultural opportunities, and land tenure arrangements.

Field and participant observations (during transect walks), focused group discussions (taking gender into account), non-standardized and largely unstructured interviews with individual farmers, farmer organizations and key informants (researchers, project workers, representatives of NGOs, and extensionists) were used in data collection. In the Savè region, landowners and settlers were added to the focus groups in order to assess land tenure issues.

Field observations were used to supplement and validate the data collected and the information gathered during the group discussions. During the transect walks, the

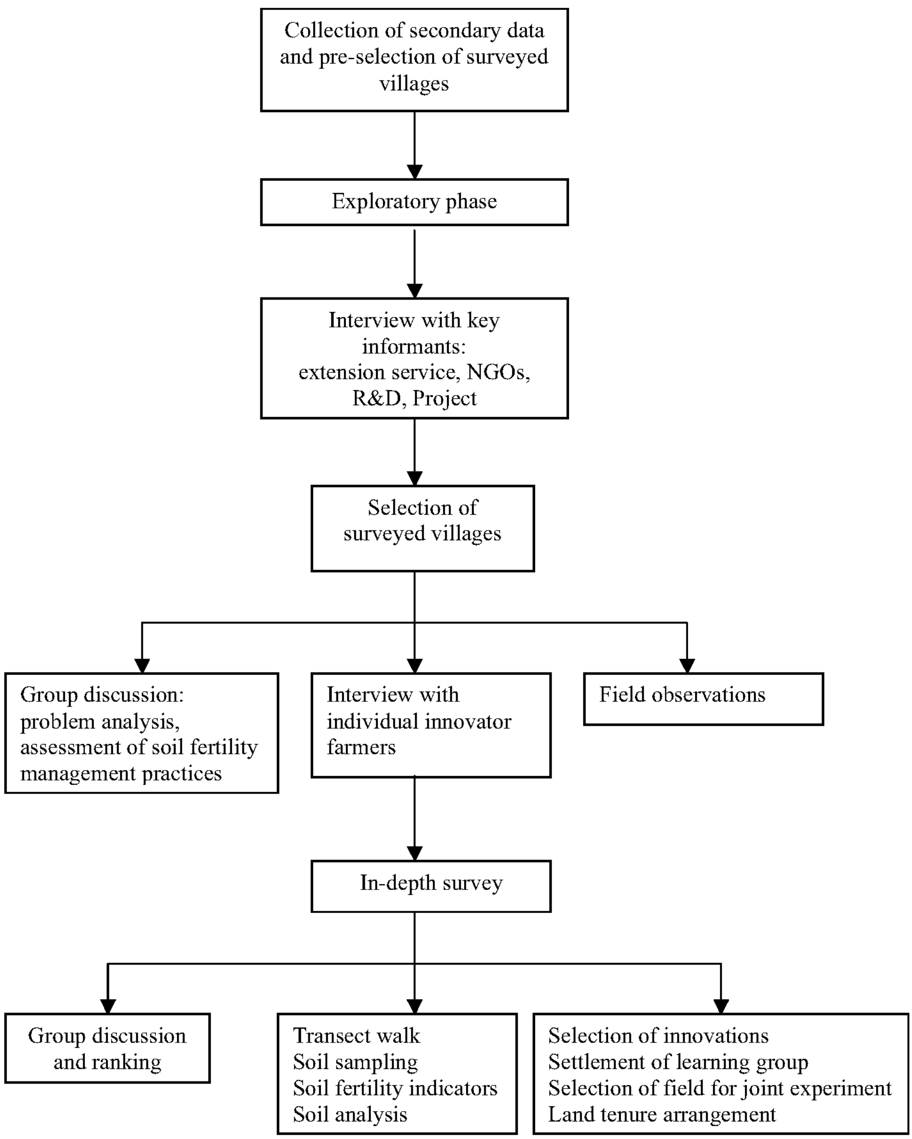

Figure 1. Diagram showing the research process.

different soil types identified by the farmers were sampled (0–20 cm). Also weeds and plant parts used by the local people as indicators of soil fertility were collected. They were identified at the National Herbarium of the University of Abomey-Calavi in Cotonou. The soil samples were analysed by the Laboratoire des Sciences du Sol, Eau et Environnement (LSSE/INRAB) in Cotonou. Analyses included particle size distribution (by sieve and pipette method after removal of organic matter, carbonates and iron

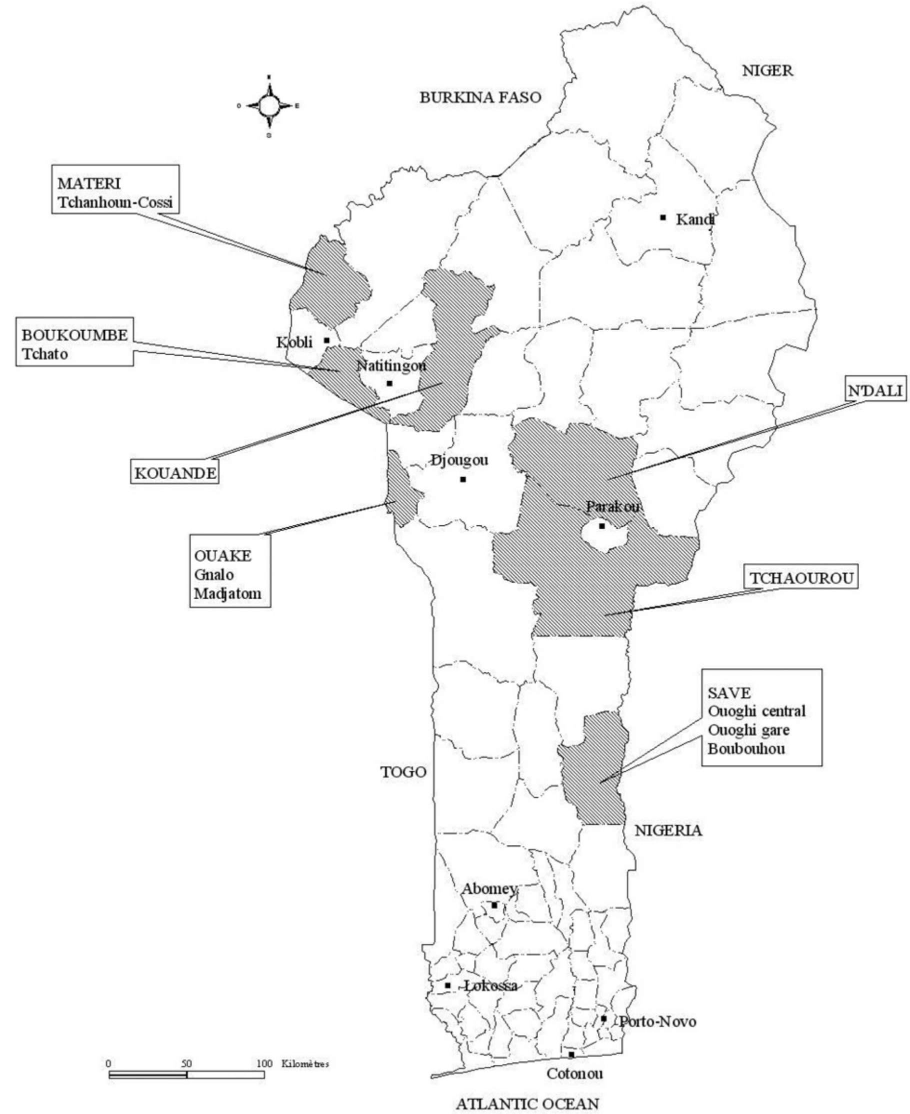

Figure 2. Map of the Republic of Benin with the districts (hatched; names in capital letters) and the villages (small letters) where the diagnostic study was carried out.

oxides), pH-H_2O (using a glass electrode in 1:2.5 v/v soil solution), organic carbon (Walkley-Black, wet oxidation procedure), and total nitrogen (Kjeldahl method). The results of the analysis were presented at a feedback session in the villages in order to strengthen contacts with farmers for the continuation of the research programme.

Results

Farmers' soil classification and inherent soil fertility assessment

In the Atacora and Savè regions some local soil names refer to the texture. The names *kubirgu* in Ditammari, *biyalic* in Biali, *kagniga* in Bufalè and *ilè ignin* in Tchabè all literally mean sandy soil. In the Atacora region also the gravel content (> 2 mm) is used as criterion for soil classification. The names *fatan'fa* in Ditammari, *sage* and *whanga* in Biali, *kuluri* in Lama and *tèyassikum* in Bufalè all literally mean gravelly soil. Most of the soil textures assessed by the farmers closely agree with those of the International Soil Science Society (ISSS) (Table 1).

In both regions, farmers' indicators for assessing a healthy or fertile soil are mainly based on:

1. Occurrence of specific dicotyledonous weeds;
2. Soil texture and hydrological quality;
3. Soil workability;
4. Soil fauna, especially earthworms.

These indicators are used by farmers to make decisions on what to grow and on the type of soil fertility management required. In the cultivated fields, farmers assess soil nutrient status on the basis of crop behaviour (growth and development) and leaf colour. In both regions they argue that pale and yellowish plants reflect some 'food' (nutrient) deficiencies. Farmers in the Savè region also use variations in soil colour as an indicator of declining fertility. Such a change in colour always occurs on the *ilè dudu* soils, which become less dark after continuous cropping.

The soil evaluations by farmers were compared with the results of the soil chemical analyses (Table 1). The soils in both regions are mostly acid to neutral: pH-H_2O ranging from 5 to 7.1. The most fertile soils as concluded from high contents of total nitrogen and soil organic matter were *fagnan'fa* (which in Ditammari literally means soil without stones and easy to work), *pahun* (in Biali), *tèyassikun* (in Bufalè), *puturi* (in Lama) and *ilè dudu* (in Tchabè). On the other hand, the poorest soils were *kubirgu* (in Ditammari), *biyalic* (in Biali), *kagniga* (in Bufalè), *kpankpandè* (in Lama) and *ilè kpukpa* (in Tchabè). The results from the soil analyses were mostly similar to the soil fertility evaluations by the farmers except for the ranking made in Savè where the *ilè kpukpa* was supposed to be a fertile soil. This contrasting result may be explained by the fact that this soil was sampled in a one year old fallow field invaded by spear grass (*Imperata cylindrica*), which is an indicator of soil degradation.

In both regions the grass species *Andropogon gayanus*, and the dicotyledonous species *Indigofera secundiflora* (in Atacora) and *Chromolaena odorata* (in Savè) are recognized as indicators of fertile soil, whereas *Hyptis* spp., *Striga hermonthica* and *Spermacoce filifolia* (in Atacora) indicate infertile soils. The abundance of witch weed (*Striga hermonthica*) in the Atacora region or spear grass in Savè (even on fertile soils) forced farmers to abandon their land (Vissoh *et al.*, 2004).

Table 1. Selected physical and chemical properties (0–20 cm) and fertility indication of the soils (in italics) named by the farmers in the Atacora and Savè regions, Benin. The local language is placed in parentheses.

Soil name/ Language	ISSS texture	Particle size (< 2 mm) Clay	Silt	Sand	Gravel (> 2mm)	Fertility indication	pH (H_2O)	Total N	Org. C
		----------- (%)			-----------			--- ($g\ kg^{-1}$)	---
Fatan'fa (Ditammari)	Very gravelly sandy loam	7.8	26.1	66.1	64.5	Fairly fertile	5.9	1.2	9.9
Fagnan'fa (Ditammari)	Gravelly sandy loam	8.8	28.4	62.8	43.0	Fertile	6.4	1.2	13.8
Kubirgu (Ditammari)	Gravelly sandy loam	6.9	28.1	64.9	33.3	Mediocre	5.9	0.6	6.6
Sage (Biali)	Very gravelly sandy loam	8.6	20.5	70.8	58.0	Fairly fertile	6.2	0.9	9.5
Pahun (Biali)	Silt loam	14.9	57.7	27.4	2.2	Fertile	6.0	1.3	15.6
Biyalic (Biali)	Sandy loam	7.0	22.4	70.5	18.7	Mediocre	5.6	0.6	5.2
Whanga (Biali)	Very gravelly sandy loam	10.2	34.6	55.3	63.1	Fairly fertile	5.5	0.8	10.2
Kagniga (Bufalè)	Loamy sand	4.8	11.5	83.8	1.4	Fairly fertile	5.7	0.3	2.7
Petaka (Bufalè)	Gravelly sandy clay loam	23.6	18.2	58.2	42.0	Fairly fertile	6.0	0.6	5.8
Tèyassikum (Bufalè)	Very gravelly loamy sand	8.8	9.0	82.2	56.3	Fertile	5.6	1.3	9.8
Tèkpê têkun (Bufalè)	Loamy sand	6.1	11.6	82.3	1.4	Very fertile	6.2	0.9	8.9
Katchika (Lama)	Sandy loam	16.5	7.4	76.1	2.5	Fairly fertile	5.0	0.4	3.9
Kangniga (Lama)	Sandy loam	11.4	9.1	79.5	0.9	Fertile	5.5	0.6	5.8
Puturi (Lama)	Gravelly loamy sand	6.5	11.9	81.6	32.8	Very fertile	7.1	1.2	7.5
Kuluri (Lama)	Very gravelly loamy sand	7.5	8.8	83.7	57.1	Fairly fertile	5.4	0.3	2.8
Kpankpandè (Lama)	Sandy loam	13.4	8.0	78.6	2.0	Mediocre	5.2	0.1	0.6
Ilè dudu (Tchabè)	Loamy sandy	7.6	11.4	81.0	0.9	Fertile	5.8	0.8	8.1
Ilè kpukpa (Tchabè)	Loamy sand	6.7	11.1	82.2	1.7	Very fertile	5.7	0.7	7.1
Ilè ignin (Tchabè)	Loamy sand	5.6	7.5	87.8	0.8	Fairly fertile	6.0	1.2	11.9

Cropping systems

Crop sequences vary according to region and soil type. Land freshly cleared from forest is cropped for up to four years. In Atacora the first crops grown are yam or cotton, followed in the second year by groundnut; maize/sorghum or cowpea. In the third year groundnut is grown or the land is left fallow (mostly on sandy clay soils). Finally, in the fourth year maize/sorghum or cassava is grown. In the Savè region, four types of crop sequence were mentioned by the farmers: (1) yam – maize or maize/groundnut – cowpea – maize/cassava or cassava/groundnut, (2) cassava – maize/groundnut – maize/cassava, (3) cassava or *egusi* melon (*Citrullus* spp. and *Lagenaria* spp.) – maize/groundnut or cotton – groundnut/maize or cotton – maize/cassava or *egusi* melon, (4) cotton – maize or maize/groundnut – *egusi* melon or cotton – cassava. After three years of cropping, the indigenous populations mostly plant cashew trees. Such a practice may be related to the land tenure arrangement as planting trees often means laying a claim on the land.

The local population in both regions mostly practises intercropping. The field is managed on the basis of the farmer's skill, i.e., farmers' knowledge about the performance of the plant and the soil. There are three intercropping systems with maize: (1) maize with grain legumes, (2) maize with sorghum, and (3) maize with cassava. Farmers know the difference between maize and grain legume roots but they do not attach importance to the legume roots, i.e., they do not know the connection between roots, root nodules and nitrogen fixation. However, farmers claim that legumes in the rotation system enhance soil fertility.

Some of the reasons for intercropping relate to the sustainability of the cropping system. However, socio-economic reasons can drive intercropping practices too. Market, food security and the need for cash money influence a farmer's decision whether he/she will intercrop maize with sorghum, with legumes or with cassava. If maize is intercropped with sorghum or cassava, maize is sown first and harvested earlier than the companion crop, allowing the sorghum or cassava plants to develop. On the other hand, maize and legumes are sown almost at the same time but at different densities based on farmer's objectives. In both regions, cotton is mostly monocropped and the subsequent crop is always maize or maize/sorghum. In this cropping pattern the subsequent cereals benefit from the residual effect of inorganic fertilizer applied to the cotton (150 kg ha^{-1} of NPKSB 14-23-14-5-1 plus 50 kg ha^{-1} of urea, as recommended by the extension service).

In the Atacora region fallow land is rare because of the strong pressure on the land. But in the Savè region, a fallow period of 3 to 5 years is observed. The sorghum stover and the cotton stalks are burnt whereas the leaves and the roots of cowpea are left to decompose in the soil. Groundnut, bambara groundnut, soya bean and *egusi* melon residues are left in the field and incorporated in the soil during ridging. In the dry season, herdsmen are allowed to graze their cattle in the maize and sorghum fields where part of the stover is consumed. Such practice can be considered as a net nutrient loss because the cattle do not spend the night in the field and so do not fertilize the soil with their dung.

In Atacora, women on their individual or collective farms often grow grain legumes, except groundnut. For example, in Matéri, women grow grain legumes on 36% of the farming area whereas only 10% is used for this purpose by men (Anon., 2001). These farmlands are mostly handed over by the women's husbands and usually consist of degraded soils. From field observations it became clear that men do the physically hard work such as mounding, ridging and land clearing. Sowing, inorganic fertilizer application in the case of cotton and maize, cow dung and house waste transportation, weeding and harvesting are done by women.

The major problems facing the farming system in the Atacora region as listed by the farmers are the rapid decline of soil fertility, weed and witch weed (*Striga hermonthica*) infestation, the high cost of inorganic fertilizers (200 F CFA[1] per kg for both NPK and urea), and finally the increasing unpredictability of the rainfall. However, a decreased water-holding capacity of the soil, due to loss of soil organic matter, may have caused the problem of an apparently lower water availability. The farmers in the Savè region mentioned as major constraints market outlet – which has to do with the low prices farmers receive for their produce – land tenure (mentioned by the settlers), decreased soil fertility, especially for the *ilè ignin* soils, and the high cost of inorganic fertilizers.

Farmers' strategies for crop production and soil fertility maintenance

Farmers cope with loss of soil fertility by implementing various practices (Table 2). In total, 11 strategies were identified in the Atacora region while only six were recorded in Savè. In the Atacora region, the strategies most preferred, both by men and women, are inorganic fertilizer combined with organic residues, inorganic fertilizer alone, cotton rotated with maize plus inorganic fertilizer (50 kg ha^{-1} of both NPKSB and urea) applied to the maize, and grain legumes rotated with cereals. Only farmers owing oxen applied cow dung. Because of transportation problems, farmers do not use cattle dung from herdsmen, who mostly live isolated from the villages. In the Savè region the indigenous farmers and settlers preferred inorganic fertilizer, extensive cassava cropping systems, and crop rotation. Extensive cassava cropping is known in French as 'jachère manioc', literally meaning cassava fallow. Strictly speaking such systems are not considered fallows as crops are still grown, but this rather extensive practice leads to a much slower degradation of the soil. In both regions, the *Peulh* people have a rotational system that allows a good distribution of animal manure on the fields surrounding the farm-house. Some of the practices are old, i.e., passed on from generation to generation, like natural fallow, the use of household waste, crop rotation and extensive cassava cropping. Other strategies have been introduced by the extension service and are new, like inorganic fertilizers and cotton rotated with maize.

Strategies to maintain soil fertility may not only involve biophysical interventions. If the productivity of the land cannot be sufficiently increased, pressure can be put off the land by migration. Emigration is a strategy used by the younger generation. The older generation generally decides to stay, and applies household waste, animal manure, or a combination of inorganic fertilizer and animal manure or household

[1]1000 F CFA = € 1.54

Table 2. Average rankings by male and female farmers of some local soil fertility management practices used in different villages in the Atacora and Savè regions of Benin. Practices listed on the basis of their relative importance in Tchato. For the soil types in the different villages, see Table 1. n = number of farmers who participated in the group discussion.

Soil fertility management practices	Atacora region								Savè region			
	Tchato		Tchanhoun-Cossi		Madjatom		Gnalo		Ouoghi central		Ouoghi gare	Boubouhou
	Male n=12	Female n=4	Male n=23	Female n=18	Male n=15	Female n=22	Male n=41	Female n=38	Male n=12	Female n=4	n=23[1]	n=25[1]
Inorganic fertilizer	1	2	4	6	2	2	2	3	1	1	1	5
Household waste	2	4	7	8	4	7	7	2	–	–	–	–
Cotton-cereal rotation	3	3	2	4	3	3	4	5	3	2	2	6
Grain legume/*egusi*[2]-cereal rotation	4	5	8	2	6	8	9	6	1	2	2	3
Crop residues incorporated	5	7	3	1	7	4	8	7	–	–	–	–
Cereal intercropped with grain legumes	6	6	6	3	5	6	10	4	5	6	–	2
Ridging/mounding	7	1	9	9	9	10	6	8	–	–	–	–
Natural fallow	8	8	5	5	10	9	5	11	6	4	5	4
Emigration	9	9	10	10	11	12	11	9	–	–	–	–
Inorg. fertilizer combined with animal dung	–		–	1	7	1	1	1	1	–	–	–
Extensive cassava	–	–	–	–	8	5	3	10	4	5	4	1

[1] Male farmers only. Because of heavy workload no women appeared during group discussion.

[2] *Egusi* melon was mentioned in the Savè region only.

waste as a way of improving soil productivity. Planting *egusi* melon and incorporating legume residues are strategies used by women. Extensive cropping with cassava or *egusi* melon, the application of household waste, and ridging/mounding are indigenous strategies. Some of the strategies are area specific. For example, the use of animal manure or household waste is specific to the Atacora region and extensive cropping of *egusi* melon and cassava is found in Savè but not in Atacora. However, extensive cassava cropping is also a strategy employed in parts of Ghana (Adjei-Nsiah *et al.*, 2004). The difference between the Atacora and the Savè region in terms of strategies concerning animal manure is cultural. The *Tchabè* people recognize the effectiveness of animal manure but socially they do not want to be confused with the *Peulh* (*Fulani* in the local dialect). Collecting cow dung is seen as useless and culturally non-acceptable. Because the soils in the Savè region are more fertile, the migrants from Atacora abandon the use of cow dung.

Farmers from the Atacora region believe that climate, especially rainfall, is the most important factor affecting soil fertility management, followed by timely ploughing, weeding and credit. Farmers' access to the extension service (providing information and knowledge) may also improve soil fertility management. On the other hand, the major constraints identified in the Savè region were credit, timely weeding and land tenure (mentioned by the settlers).

Land tenure arrangement in the Savè region

The results from the exploratory survey done in the Savè region showed that the percentages migrants in Tchaourou and Savè were 28 and 37, respectively. Most migrants belonged to the following ethnic groups: *Ditammari* and *Yom* from the Atacora region, *Fon* from Abomey plateau and *Idatcha* from Dassa-Zoumè and Glazoué. The migrants, especially the youth – because their fathers are still alive and use the land – after having been confronted with soil degradation leave the village for better living conditions in an area where the soils are more fertile.

Two categories of migrants can be distinguished. The first category comprises those who have settled in the area and who once a year return to their native village to fulfill ritual duties. The second category consists of young people who come temporarily to the region and work as seasonal labourers for the indigenous farmers and for migrants of the first category. After the season they return home with money and purchased goods like a motor bike, bicycle and radio/cassette recorder.

In the past there were no strict land tenure arrangements between established migrants and landowners. After one or two years working for an indigenous farmer, the migrants wishing to stay in the village could acquire land from the landowners (represented by the *Ballè*, literally meaning 'father of the land'). Land is acquired in a traditional way and consists of exchanging gifts and making a contribution to the ceremonies held by the landowner. In the past a member of the *Ballè*'s family did such transactions. A large number of immigrant villages have been established in that way. Nowadays the number of immigrant villages is increasing and the land tenure arrangement has changed.

Since 1999, only the 'Comité de Gestion des Terres' in Ouoghi central village, which was created by the village development association (ADESVO), is authorized to arrange contracts with migrants. This committee reports to the village development association including the *Ballè* who is also the chief of the village. After the harvest, the migrants pay a substantial rent for land use. Over a period of five years, the rent in Boubouhou had been increased from F CFA 2000 to 10,000 per hectare per year against an increase from F CFA 2000 to 6000 in Ouoghi gare. The rent, which does not depend on the actual yield obtained from the land, has to be paid, otherwise the tenant is evicted from the land. The consequences of this are overuse (to get more profit from the land) and, hence, land degradation. The terms of the contract do not allow the settler to plant trees. Planting trees is seen as a form of land appropriation. Most of the settlers have their farms on the marginal land *ilè ignin*, which cannot be cropped for more than four years. When it comes to leave the land fallow, the landowners plant cashew, which prevents the settler to come back on these lands. As a result, most of the migrants of Ouoghi gare have their farms far away (4–8 km) from the village.

Discussion

Farmers' soil classification versus classification based on soil science criteria

Farmers' criteria for soil classification are user-oriented and based on the (potential) fertility and on physical properties that affect workability. The most important local criteria for soil classification, as applied by farmers, are based on colour and texture. These criteria are similar to criteria used elsewhere in West, Central and Southern Africa as observed by De Steenhuijsen Piters (1995), Murwira & Mukamuri (1998) and Ishida *et al.* (2001). Soil colour provides qualitative information about soil organic matter content. The darker the soils, the more organic matter they contain and the more fertile they are. Light-coloured (brownish) soils contain less organic matter and are, therefore, less fertile. Such observations made by farmers are in agreement with results of soil chemical analysis. Land evaluation by farmers is not only related to chemical soil fertility but also to soil texture (physical aspects of soil fertility). Farmers define soil texture by the soil's water-holding capacity, which is related to soil organic matter content. Indeed, soil rich in organic matter has a higher water-holding capacity, and thus has better textural characteristics. The perception of soil texture by farmers of Atacora and Savè regions is similar.

From this study it has been learned that farmers are well aware of the beneficial effect of earthworms in the management of the agro-ecosystem. The abundance of earthworm casts is used as soil fertility indicator in both regions. In fact, earthworms positively affect soil fertility by maintaining soil structure, by enhancing soil nitrogen mineralization, and by bringing back to the surface, through their casts, nutrients that would have otherwise leached (Henrot & Brussaard, 1997). Ants and termites may also have a positive effect on soil fertility, but farmers did not mention ants, whereas termites were valued negatively as destroyers of crops.

Farmers' strategies for crop production and soil fertility maintenance

Farmers in both regions have developed and/or inherited complex farming systems that have helped them to meet their subsistence needs. For instance, farming systems in which animal manure is used have allowed the farmers to improve resource use efficiency. Farmers in the Atacora region argue that animal manure combined with inorganic fertilizer is the most effective way of maintaining soil fertility and improving yield. Such a strategy is often called integrated plant nutrient management (Janssen, 1993).

The extensive cassava cropping system, which is claimed by farmers in the Savè region as a system that regenerates soil fertility, also has a financial risk-minimization function. Harvesting is flexible in time, i.e., roots are harvested when there is a need for cash, leaving the cassava for about 18–24 months in the field. Farmers attribute soil improvement by extensive cassava cropping to the ability of the cassava to form a dense canopy that protects the soil from the impact of solar radiation and rain. Its high litter production (especially if the litter is rich in N, P and K), when decomposing together with the roots left unharvested, contributes to the regeneration of soil fertility. This phenomenon is not well understood, because conventional science considers cassava a nutrient-depleting crop (Silvestre, 1987; Sitompul *et al.*, 1992) when harvested after 6–9 months. So it is important to test, together with farmers, the validity of their claim. Such tests should include studies about the role of different cassava cultivars, the magnitude of the effect, and the possible mechanisms involved. Extensive cassava cropping may mean lower nutrient extraction. Cassava rooting patterns and/or mycorrhizal association may lead to enhanced phosphorus-availability, and a favourable microclimate may increase soil biological activity. The system should be part of further scientific investigations to test which cassava landraces have this beneficial effect and on what types of soil.

Like all members of the Cucurbitaceae, creeping *egusi* melon cultivars grown in the Savè region produce a lot of biomass that covers and protects the soil against the negative effect of solar radiation and runoff. As with extensive cassava cropping, the favourable microclimate may stimulate soil fauna activity, especially of earthworms. If soil moisture is not limiting *egusi* leaves decompose rapidly and improve soil fertility. The potential role of *egusi* melon in enhancing soil fertility has never been investigated by conventional science. Further investigations are needed to test which *egusi* landraces may regenerate soil fertility efficiently. Such research should explicitly include earthworms. Farmers associate the presence of earthworms with fertile soils, while at the same time overlooking a possible causal role of earthworms in the maintenance of soil fertility.

The differences in soil fertility management strategies rankings between the villages and regions are large. This may be due to differences in pressure on farmlands, ethnic differences, cultural differences, differences in soil quality, in rainfall or in agronomic practices. For example, the agro-climatic conditions in the Atacora region do not allow the cultivation of cassava and *egusi*, and the soils in the Savè region are rather fertile. The difference in soil fertility management strategies between the Atacora and Savè region reflects the differential need for soil fertility management, the different availabilities of animals especially oxen, resource availability, and tradition. These differences lead to differences in pressure on the land and to different solutions. At a higher level, however, these solutions are interconnected, as emigration from Atacora relieves local pressure but increases pressure on the land in the Savè region. Solutions in Savè through tenure arrangements may lead to different options for migrants, and young migrants come as seasonal labourers from Atacora to Savè, whereas the money earned with their labour flows from Savè to Atacora.

Land tenure arrangements: a prisoner's dilemma?

It is not easy to find a neutral language for describing the effects of land tenure arrangements on soil fertility management. Are landlords 'forcing' the immigrant settlers to mine the soils? Are migrants trying to maximize 'immediate profit' while disregarding long-term sustainability? Or is the increasing monetarization of agriculture leading to a situation that can best be described as 'prisoner's dilemma', where both parties act rationally in the short run, even if the final outcome is soil degradation? In his article 'The tragedy of the commons' Hardin (1968) highlighted the importance of this prisoner's dilemma in land management. Hardin refers to a similar situation, i.e., individuals maximizing their own short-term benefit even at the expense of the long-term common good. However, this tragedy only occurs under a number of assumptions that may not pertain to our case. Hardin's 'tragedy of the commons' assumes an atomistic society where all individuals play symmetrical strategies, and where there are no institutions to regulate co-operation and conflict. Under these conditions Hardin's solution, i.e., private property of the land, may be the only solution. In cases where there are institutions like tenure arrangements, even if these institutions are weak or asymmetrical, a larger range of solutions is possible. But it is important to emphasize that adherents of the neo-Boserupian view that increased populations can also improve the fertility of the land, mention the importance of security in tenure arrangements as a necessary condition (Tiffen & Mortimore, 1994; Fairhead & Leach, 1995).

In the Savè region there is a basic asymmetry because of property rights on the land, so power relations enter the interaction. The best way out of the prisoner's dilemma is through the build-up of mutual trust. So it is important to understand the factors that enhance or diminish mutual trust (see Adjei-Nsiah *et al.*, 2004). Both parties are also heterogeneous and each may have a variety of potentially conflicting interests. Seasonal migrants may be different from migrants who finally settle in the village and return only once a year to their original village to participate in the annual rituals. Older landlords with share-cropping arrangements may be different from their younger fellows who prefer financial arrangements. And finally, there is a socio-economic dynamism, where monetarization of agriculture is of increasing importance: changes from subsistence agriculture to cash-crop agriculture, expanding markets due to better transportation facilities, and hence diminished control by producers over prices at local markets.

Both diversity and dynamism affect the space that is available for experimentation among farmers and farmer groups for alternative arrangements. Do land-for-labour transactions (share cropping) enhance mutual trust more efficiently than land-for-money transactions? If so, does the change in arrangements reflect a loss of trust? But is it possible to go back to the older arrangements or are these irretrievably lost? Does people's willingness to engage in novel arrangements weaken their position within their group? Should such agreements therefore be handled collectively on a community platform or should space for negotiation be sought among individual villagers without the risk of group pressure? Game theory suggests that increases in group-size reduce the likelihood of making stable arrangements, as failure to comply with the negotiated arrangements could take place both between and within groups. And finally, to what extent is the situation in the Savè region context-specific and to what extent are global processes important? Considering similarities between conflicts about tenure arrangements in this study and in the study in Ghana (Adjei-Nsiah *et al.*, 2004), this question is relevant as well.

Whereas the diagnostic study itself has not provided answers to these questions, the study did show how much soil fertility issues are embedded in tenure arrangements, and how these are embedded in a village or world of power and trust. The diagnostic study has at least clarified that a rough approach, which attributes 'guilt' to immigrant settlers or landlords and for which a community-wide platform provides the only way out of this dilemma, runs a risk of failure. It is clear that experiments in the social domain of tenure arrangements have to be an important element of the next research phase.

Reflections on the diagnostic study as an entry point for understanding farmers' practices and attitudes towards sustainable soil fertility management

What difference does this diagnostic study make? Does a diagnostic study have to start by assessing all of the village problems and farming constraints while knowing that not all of these could be studied or resolved? This question raises the problem of background knowledge and disciplinary specialization needed for a diagnostic study. However, a diagnostic study should make these implicit considerations explicit. In retrospect, it is clear that the diagnostic study led to changes. Tangible results of this approach were (1) the way villages were selected, (2) the strategies that were adopted to involve farmers in the research process, (3) the interactions between farmers and scientists and the ways farmers challenged us to accept their findings, (4) the agreement that came up for the continuation of the study, and (5) the implications of the results of this diagnostic study to fine-tune the final research proposal. More importantly, the diagnostic study has led to the identification of new research areas that were not taken into account in an earlier phase. Without it we would have missed farmers' knowledge about the importance of earthworm activity and of litter decomposition related to soil fertility regeneration. We would also have overlooked the connections between landowners and settlers, land tenure arrangements and soil fertility management.

Fifteen villages were visited as part of the diagnostic study, but only seven were selected for the in-depth study and three for the continuation of the research programme. Starting with a larger number of villages and subsequently zooming in gave the opportunity to have a wide overview, which may not have occurred had the diagnostic study been carried out in one village only. How representative are the seven villages that were selected for the in-depth study? At this stage we can only say that it were these villages that showed most interest in the project.

The diagnostic study has led to a framework for an effective interactive research approach (Figure 1) on soil fertility management. This approach is an alternative to the top-down approach that has often led to failure of introduced soil fertility management innovations. Instead of adopting externally designed technologies, our approach intends to enhance a joint learning process where we learn from the farmers and in return farmers learn from us. Both farmers and researchers have the chance to challenge each other in order to develop innovations that are effective from a technical point of view and that also are socially and culturally acceptable. The research agenda for the subsequent phase of experimentation is then 'negotiated' with the farmers.

The main issue raised in this diagnostic study was how to find a common framework in which farmers' perception converges with theories of conventional science about the extensive cassava and *egusi* melon cropping systems. In order to test the validity of farmers' claims, we agreed to investigate the potential of extensive *egusi* melon and cassava crop rotations as a means to restore soil fertility and maintain adequate crop yields. For the joint learning process, we exchanged knowledge about symbiotic relationships between plant and micro-organisms, especially mycorrhizal associations with cassava roots that improve nutrient and water uptake, and rhizobia (nitrogen-fixing bacteria) that form nodules on legume roots. Fresh groundnut roots and fine cassava roots were shown during a group meeting. Specific emphasis was placed on the active root nodules that when severed exhibit a red colour like blood. Farmers were willing (and curious) to have a specific study on mycorrhizal relationships of cassava, which could improve the supply of phosphorus – a major limiting nutrient – to the subsequent maize crop. Furthermore, farmers will become owners of the research findings. Evidently, such an approach is costly in terms of time and requires that the research team stay as close as possible to the farmers' community. This is even more important in view of the need to engage in discussions and experiments with alternative tenure arrangements.

The next step envisioned consists in the design of a community based research committee including farmer innovators. Such a research committee will be based on farmers' free choice implying that farmers interested in the research activities may deliberately join the group. This strategy, which avoids discrimination among villagers, undoubtedly may present some disadvantages with a large group. So farmers will be involved in the research process to achieve a better dissemination of technology. In such a committee the concept of democratization of science can be taken seriously when farmers and researchers engage in research discussions on an equal basis. Such a system using an interactive approach aims to build local capacity. In this research process, knowledge is generated through building on farmers' experiences and through learning by doing. The farmers are moved and move themselves towards the centre of the research process. However, as indicated above, neither the scientists are marginalized in that process.

The participation level (16–79 participants as shown in Table 2) in the community meetings, the liveliness of the debate and the way farmers defended their claims are indicators of their interest in the new approach experimented. This has been facilitated by the way the researcher was introduced in the community by the local extension agent, viz., as student coming to learning from them.

In the specific context of land tenure, we may start with a joint understanding that present arrangements are unfavourable for the settlers and also unfavourable for the original inhabitants, because land resources are degrading. There is a need to explore possibilities of creating new tenure arrangements between landowners and settlers. It is an open question whether such arrangements should be discussed and negotiated among individuals or within community-wide platforms. The critical issues that affect sustainable land resources management must be gathered. Testing alternative tenure arrangements may ultimately be as important as directly testing alternative soil fertility management strategies.

Conclusions

Farmers have insights and adaptive skills that are based on years of experience. This body of knowledge and learning capability has often been accumulated and communicated over generations. In the Atacora and Savè regions of Benin, soil names used by farmers reflect soil colour, texture, coarseness, and hydrological qualities or soil workability. The main purpose of the indigenous soil classification is to indicate farmers the type of soil management required. Mostly, soil fertility evaluation by farmers gave similar results as soil chemical analysis.

Soil degradation is one of the major problems facing farmers in the regions studied. They cope with soil fertility degradation by developing alternative strategies that include the use of organic residues, inorganic fertilizer, crop rotation, and extensive cassava and *egusi* melon (*Citrullus* spp. and *Lagenaria* spp.) cropping systems. These two cropping systems are not well understood, because conventional science considers that cassava contributes strongly to nutrient depletion while *egusi* melon has never been object of research. Their contribution to soil fertility regeneration should be part of further scientific investigations, involving all stakeholders in the research process.

Driven by land degradation elsewhere, farmers from Atacora and the southern regions of Benin migrate to the Savè region. Landowners charge the migrants rent for land use and as a consequence these migrants do not invest in long-term soil fertility management practices. The study has shown how much soil fertility issues are embedded in tenure arrangements, and how these are embedded in a village or world of power and trust. The establishment of a platform for negotiation among the stakeholders may come up with sustainable land tenure arrangements that take into account the interests of both the landowners and the migrant settlers. It may encourage the migrants to invest in long-term soil fertility management.

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