Farmers' Perceptions of Soil Fertility in Benin

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Abstract

An analysis of farmers' knowledge of alternative techniques to improve soil fertility, particularly their perception of the benefits and costs, is essential for explaining why farmers adopt measures for soil fertility improvement. Inevitably if farmers are unaware of certain techniques or their benefits then there will be no uptake. Therefore a key question to be addressed is what benefits do farmers expect to gain from different soil fertility regimes.

The benefits of soil fertility management fall into three main categories: an extended cropping period, an increased yield and a wider crop choice. This paper examines each of these advantages based on the results of a survey undertaken among farmers in Atacora region, Benin. The survey aimed to investigate what farmers were *planning* to do in the coming five years, and to compare these plans with their actual behaviour, focusing on the different combinations of crop and soil fertility management regimes. We also examine the monetary benefits of different crop and technique choice using a regression analysis, and the constraints to farmers to achieving the optimal combination.

Resumen

Con el objeto de explicar las razones por las cuales los agricultores adoptan medidas para mejorar la fertilidad de la tierra, en particular su percepción de los costos y beneficios, es esencial analizar el conocimiento a disposición de los agricultores de técnicas alternativas para dicho mejoramiento. Es evidente que los agricultores no adoptarán técnicas de las cuales no tienen conocimiento , o si no son conscientes de los beneficios que pueden reportarles. Por consiguiente, es muy importante identificar cuáles son los beneficios que los agricultores esperan obtener con relación a diversos regímenes de fertilidad de la tierra.

Los beneficios de la gestión de fertilidad de la tierra se pueden clasificar en tres categorías principales: más amplios períodos de cosecha, mayores rendimientos y mayor variedad de cultivos. Esta monografía examina cada una de estas ventajas de acuerdo a resultados obtenidos en un estudio realizado entre agricultores en la región de Atacora, Benin. El objetivo del estudio era el de investigar qué planeaban hacer los agricultores en los siguientes cinco años, y comparar esto con su comportamiento real, centrándose en las diferentes combinaciones de cultivo y regímenes de gestión de fertilidad del suelo. También examinamos los beneficios monetarios de diversos cultivos y las opciones técnicas utilizando un análisis de regresión, al igual que los obstáculos que se les presentan a los agricultores para lograr combinaciones óptimas.

Résumé

Afin de comprendre pourquoi les agriculteurs adoptent certaines mesures d'amélioration de la fertilité pédologique, il est essentiel d'analyser leur connaissance des techniques alternatives disponibles en ce domaine, en particulier leur perception des coûts et bénéfices. Si certaines techniques (ou leurs avantages) ne sont pas portées à la connaissance des agriculteurs, il est inévitable que ceux-ci ne les adoptent pas. Il s'agit donc de se poser une question-clé: quels avantages les agriculteurs espèrent-ils tirer de différents régimes de fertilité pédologique.?

Les retombées favorables d'une gestion de la fertilité pédologique sont à classer en trois grandes catégories: une période de récolte prolongée, des rendements accrus et un plus grand choix de cultures. Ce travail examine chacune de ces catégories à partir des résultats d'une enquête menée auprès des agriculteurs de la région d'Atacora, au Bénin. Cette enquête avait pour but de comprendre ce que les agriculteurs *prévoyaient* de faire au cours des cinq années suivantes et de comparer ces projets à leur comportement réel durant ces cinq ans, s'agissant des différentes combinaisons de culture et de régimes de gestion de la fertilité pédologique. Nous envisageons aussi, à l'aide d'une analyse par régression, les

retombées financières de différents choix de cultures et de techniques et nous examinons les contraintes subies par les agriculteurs dans leurs efforts pour parvenir à une combinaison optimale.

Introduction

An analysis of farmers' knowledge of alternative techniques to improve soil fertility, particularly their perception of the benefits and costs, is essential for explaining why farmers adopt measures for soil fertility improvement. Inevitably if farmers are unaware of certain techniques or their benefits then there will be no uptake. Therefore a key question to be addressed is what benefits do farmers expect to gain from different soil fertility regimes.

The benefits of soil fertility management fall into three main categories: an extended cropping period, an increased yield and a wider crop choice. Of these an increased yield is the most obvious advantage but it generally takes time for these to show – time when costs are being incurred. Yet some techniques take longer than others. For example, mineral fertiliser impacts on yields very quickly compared to improved fallow where there is a long delay.

An increased cropping period is a second advantage of soil fertility management. In fact fertiliser is now substituting the traditional fallow necessary to regain soil fertility. This is only an advantage when there is limited access to new land. In the old shifting cultivation system a farmer would move to a new plot when the advantages of using a new, more fertile, plot outweighed the extra labour costs in clearing it. In this situation, extending the cropping period by investment in the old plot provides little benefit compared to the benefits of investing in new fertile plots.

Some crops are only profitable if certain fertilisers are used, eg cotton, which is always grown with mineral fertiliser in the Atacora. Some farmers indicate they only grow maize when they have access to mineral fertiliser; indeed there would be no harvest without it. Therefore, access to fertilisers not only provides farmers with a wider choice of crops, but also ones which, because they are more valuable, may secure a higher returns.

This paper examines each of these advantages based on the results of a survey undertaken among farmers in Atacora region, Benin. The survey aimed to investigate what farmers were *planning* to do in the coming five years, and to compare these with their actual behaviour. Farmers' estimations of the cropping period using different techniques will be analysed in the first section. The following section will discuss farmers' crop choices combined with different kinds of fertilising techniques. We will then examine the yield differences that farmers expect when using fertilising techniques in the short, medium and long-term. In these three sections we will only look at physical changes.

We also examine the monetary benefits of applying different fertilising techniques to different crops. This allows us to make a better comparison between crops and to explain why technique is dependent on crop choice. We do this by means of regression analysis. However, fertilising not only benefits farmers; there are also costs, mainly in terms of labour and cash, which must also be taken into account.

Although we asked farmers to report on soil fertility regimes they knew or used, a full description of their soil management practices cannot be expected to emerge from this approach. The research focuses on rural people's knowledge of *specific* techniques, ie those that are widely used, including fallow, mineral fertiliser and animal manure, and those actively introduced by extension services. For some farmers, knowledge of a specific technique may be completely lacking, others may know of it, and still others may have some experience with the technique. It is beyond the scope of this study to describe the farmers' knowledge regarding all fertilisation practices. The study was not designed to give a description of all (indigenous) fertilisation techniques used in the Atacora.

The Survey Area

The Atacora region, situated in the north-west of Benin, covers almost one third of the surface of Benin (see Figure 1). The region is characterised by the Atacora mountain chain, with altitudes varying from 400m in the south to 650m in the north. These mountains are the source of many rivers and water-basins, making the region suitable for the production of rice in certain shallows. However, the mountainous region is very vulnerable to erosion; moreover it is largely inaccessible and roads are very difficult to maintain.

The climate in the Atacora is semi-arid. There is one rainy season (mid-April to mid-October), and annual precipitation varies from 1,200 - 1,300 mm in the south and centre to 900-1000 mm in the north and the east. With only 21 inhabitants per km^2, the Atacora is the most sparsely populated region in Benin after the Borgou. Its population is largely agricultural (92%). In 1992 77,289 agricultural households were registered with an average size of 7.6 persons per household (INSAE, 1994). On average, 4 workers are available per farm. Around 47% of the total area is suitable for agriculture. Per agricultural household this amounts to 19 ha of arable land (MDR, 1993) of which no more than 2.37 ha are cultivated (MDR/DAPS, 1995). There are large differences in population density within the Atacora.

According to climate, soil type and cropping practices, we can distinguish four agro-ecological zones (CARDER-Atacora, 1993)[1]. The north-west zone roughly coincides with the administrative districts of Boukombé, Tanguiéta, Matéri and Cobly. The climate is of the Sudan type with precipitation between 800 and 1100 mm per year. The shallow, ferruginous soils have a low water holding capacity and a low natural soil fertility. The zone, which is linked by the mountain range, is rather densely populated (emigration zone), especially the district of Boukombé. Maize, sorghum, yam and cowpea are the principal crops. Hardly any mechanisation is used.

The north-east zone coincides with the administrative districts of Kérou, Kouandé and Péhunco. It has a Sudan-Guinean climate and an annual rainfall of between 1100 and 1200 mm. The tropical ferruginous soil has a sandy subsoil, which are still rather deep and fertile. Vegetation consists of savannah shrubs, dominated by *Acacia siébériana* and *Butyrospernum parkii* (Shea, or karité). Climatic and soil conditions, combined with the widely used oxen-plough, favour a range of crops: cotton production is well developed and maize is gradually replacing millet. Land availability is still good.

The centre zone consists of Copargo, Ouaké, Toucountouna, Natitingou and a part of Djougou. The climate is Sudanian with an annual rainfall between 1200 and 1300 mm. The tropical ferruginous soils are often pebbly but profound and have a moderate fertility. The soils are sensitive to leaching. The ecosystem in this region is one of tree savannah evolving into a bush savannah. The main crops grown are yam, sorghum and millet.

The fourth south zone includes the district of Bassila and the south of Djougou. The climate is Sudan-Guinean with rainfall varying between 1100 and 1200 mm per year. The ferruginous soils on a sandy base are profound and fertile. There is a savannah vegetation with shrubs and

[1] In 1995 the MDR (Ministère du Developpement Rural) drew up a new division of the agro-ecological zones. We have used the old division of zones.

trees. The zone includes large areas of listed forests, but these are intensively exploited. Groundnuts, maize and cowpea are the main cultivated crops.

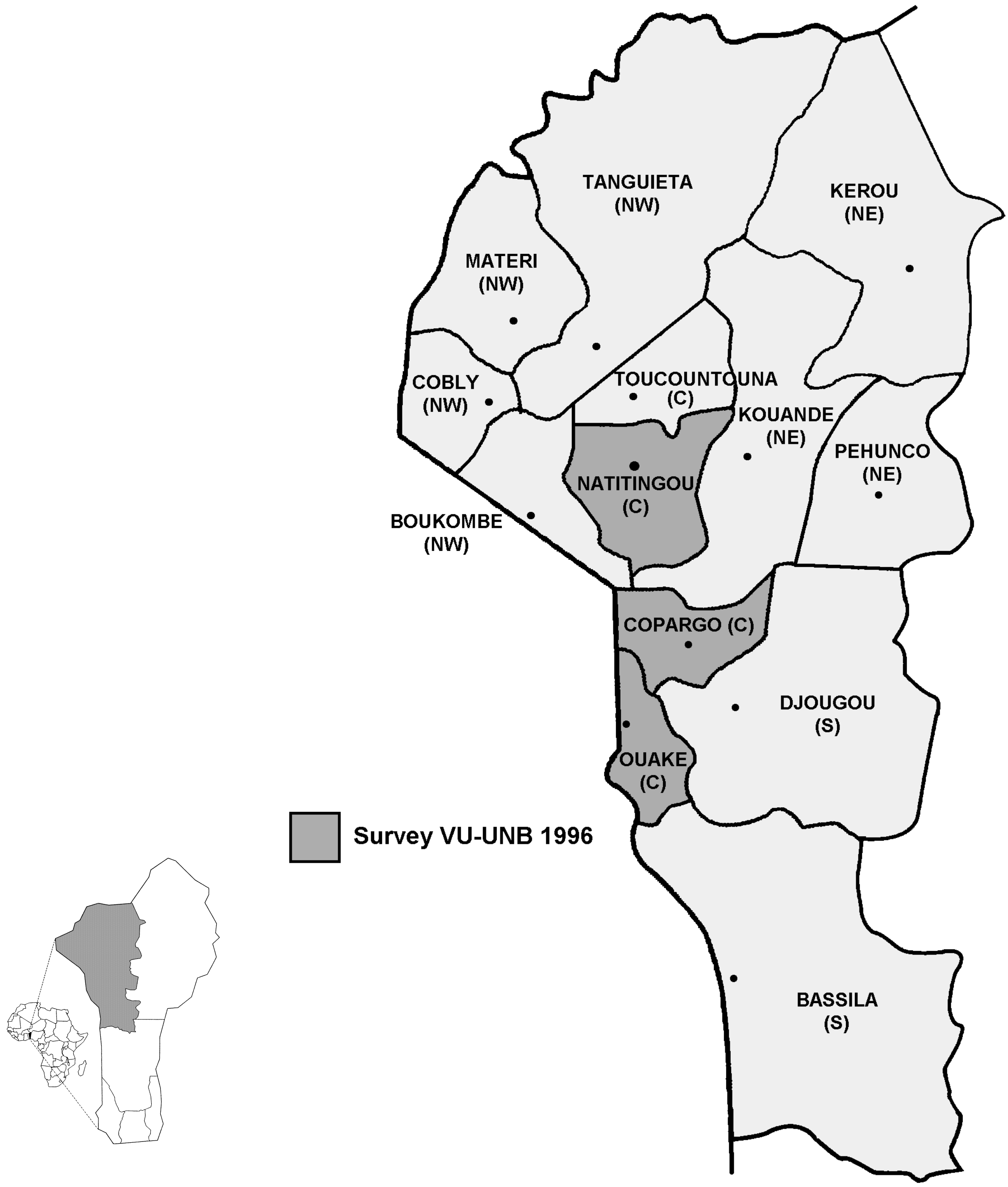


Figure 1 The Atacora Province in Benin

Methodology

It is extremely difficult to ask farmers to quantify the effects of soil fertility management. This difficulty is compounded because in practice, farmers use several techniques simultaneously, and none is used permanently. As a result it is difficult to attribute specific outcomes from individual techniques when we only have a three year cropping history of each plot. Moreover, decisions to adopt techniques are based on what farmers *think* the effects are. Therefore, we decided to use a forward planning approach, asking farmers opinions on yields and cropping plans over the coming five years using three possible fertiliser techniques.

The use of a forward planning approach is difficult for a farmer. However, recalling actual behaviour over a longer period has its drawbacks as well. Moreover, in the future planning approach we can assume that results are not affected by special climatic circumstances, which may be the case with recalling. The results of this paper are based on farmers' expectations instead of actual behaviour, although the expectations are sometimes compared to actual behaviour.

One section of the questionnaire was designed to reveal farmers' opinions on the effects of fertilising methods on the short and medium-term yields. For each farmer, one or two plots were chosen in the following way. We defined cash crops - cotton, tobacco and groundnut. All plots with one of these crops on it in the 1994/1995 season were referred to as cash-crop plots[2,3]. All other cultivated plots were considered food plots. For each farmer, we selected one food-crop plot and one cash-crop plot wherever available.

Farmers were asked to give a production plan for the coming five years for both plots. A *production plan* is defined here as the succession of crops the farmer is planning on a certain plot, including the fallow periods planned; an alternative name is *rotation scheme*. We refer to the production plan the farmer is actually planning as the 'actual' production plan. Additionally we asked which fertilisation methods they were planning to use in each of these five years. Next they were asked to estimate the yield of the plot for the season 1995/1996 and for the season 1999/2000, given the production plan and techniques the farmer planned.

Problems with definitions of techniques or a mismatch of technique names were avoided in the following way. Each village in the survey had its own interviewer who also an interpreter. Before the survey got underway, the interviewer obtained the local names of each technique by describing them at a general meeting. This procedure was repeated at each farm when the farmer did not know the local name. Some techniques described in Box 1 are rarely mentioned by farmers (eg, green manuring and mulching), and are included in the category 'other' techniques in the analysis.

[2] These crops were considered cash crops even when the farmer did not sell any part of the produce.
[3] Since the cultivation of tobacco was insignificant, no results on this crop are presented in this paper.

Box 1. Descriptions of fertilising techniques in the VU-UNB survey	
ordinary fallow	- land is not exploited for one or more agricultural seasons to restore, at least partly, soil fertility
improved fallow	- legumes or other crops/trees are planted during the fallow and not harvested, with the purpose of improving soil quality.
mineral fertiliser	- mineral or chemical mixtures bought in bags that are used to improve yields.
residue incorporation	- crop residues and weeds raked into the soil, instead of burnt, to fertilise the following crop.
green manure	- intercropping with legumes or other plants in order to fix nitrogen and then incorporate them into the soil for the following crop.
parking	- cattle are brought in to occupy the plot, usually during the night. The soil benefits from the animal waste. .
animal manure	- manure is collected from elsewhere and transported to the field.
composting	- a decomposed mixture of crop residues, soil and animal dung which is used to fertilise the soil.
mulching	- spreading out over the plot a surface of grasses, crop residues, straw or leaves, usually transported from elsewhere. (The mulch decomposes, decreases run-off, avoids erosion and attracts termites.)
agroforestry	- annual crops are intercropped with perennial trees or shrubs. (Deeper rooted trees can exploit nutrients not available to regular crops. The trees and shrubs provide mulch and avoid erosion.)

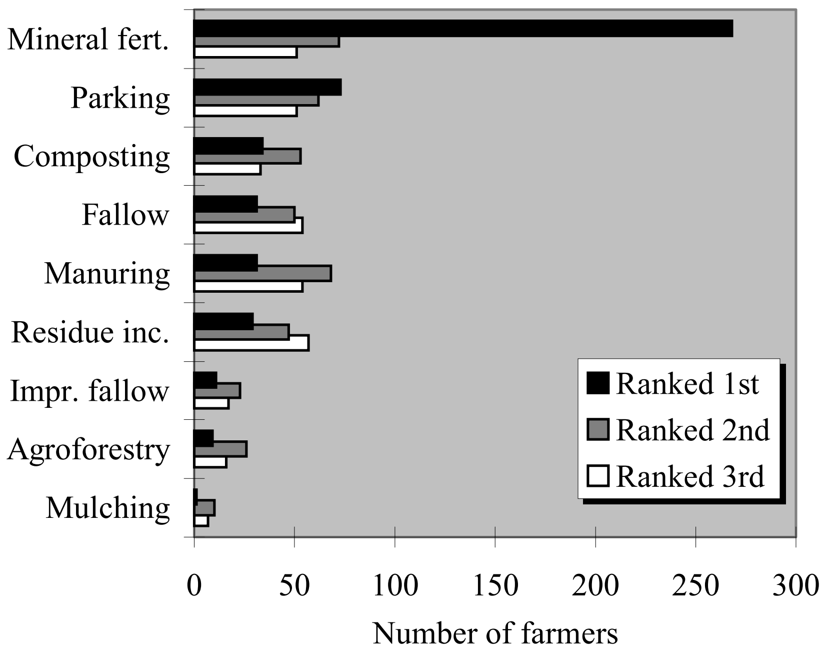
Note: Explanations between parenthesis were not given to farmers when describing the techniques.

In order to obtain farmers' views about the effects of fertiliser techniques on agricultural production in the medium term, their estimations should be compared to a situation where these techniques are not used. The two situations may differ not only in yields, but also in crops grown: sometimes farmers change the crops they grow when a different technique is used. We asked farmers what production plans they would use in the hypothetical case of 'no fertilising techniques' except fallow. This production plan is referred to as the '*without*' production plan.

A third production plan and corresponding yields were registered in the hypothetical case that each farmer used the technique he ranked first (see Figure 2), in each of the 5 years when not in fallow. We refer to this production plan as the 'best' production plan.

By comparing the three production plans and the corresponding yield estimates we can analyse farmers' expectations of the benefits of soil fertility management. By analysing the differences in cultivation period between the three plans we can study how farmers would substitute for fallow by using fertilisation. We will look at differences in crop choice for each production plan and whether crop choice can explain technique choice or vice versa.

Figure 2 Farmers' ranking of soil fertility methods



Source: Survey VU-UNB (1995).

For each production plan we have yield estimates from the farmers for the first and the fifth year. The analysis of yield estimates from two years cannot completely reveal the way yields are expected to respond to soil fertilising techniques in the long run. However, we can use the results to reveal the order of magnitude of yield increases farmers expect from fertiliser. The reason for these rather elaborate production plans is that crop choice as well as cropping period may change with technique choice. When asking only the difference in yield these two aspects cannot be taken into account.

The yield estimates for the 'actual' and 'without' production plans are a reflection of the effect on yields of the planned fertilising techniques. However, as we have seen before, farmers do not permanently use fertilising techniques. Some farmers do not use any techniques at all, while others use a technique only once in several years. To be able to better judge the effects of more intensive fertilising, we asked the farmers for their estimations when a technique is practised more permanently. Therefore the 'without' production plan will be compared with the 'best' production plan (Section 2).

Management of soil fertility brings costs as well as benefits. There is always a requirement for labour, but not all techniques are equally labour intensive. The collection of manure for manuring or making compost can be very labour intensive, especially when the household does not have cattle and the farmer has to collect manure in the bush. For compost a pit needs to be dug. Additional crops or trees need to be grown in the case of agroforestry and green manuring. These extra crops compete for the same scarce labour as other crops. Fertilisers need to be spread over the field as well. For mineral fertiliser this is probably the only labour cost involved, although additional efforts are required to transport fertiliser from the market to the fields. For farmers who do not grow cotton mineral fertiliser is not always easily available in their village. In addition to labour, a payment in cash or in kind may also be required. Mineral fertiliser needs to be paid in cash. Sometimes credit is available, but cash is still needed eventually to pay off the credit. A payment in kind or in cash is also necessary for parking animals of the Peulh.

We did not ask farmers to estimate the extra costs in terms of labour and cash for the planned fertiliser use. However, for the centre zone we do have information on actual labour use and costs of labour from the VU-UNB 1996 survey for the 1995/96 season, and the cost of mineral fertiliser for 1992-1995. We can use these costs to compare them to the benefits of fertilisation (Section 3).

Before turning to the analysis of the benefits of fertilising, we will discuss technique choice in the three production plans and we will compare planned with actual use.

Planned Use of Soil Fertility Measures

Table 1 illustrates what farmers indicate they would use in the coming years under the 'actual' production plan (see Table 1). Most techniques would be used in approximately the same proportion over the years. The share of plots on which no technique is practised is decreasing over the years. Unfertilised plots need to be put to fallow sooner and their share will decrease. The use of residue incorporation drops after the first year, although it is not clear why this happens. When we look at the table for cultivated plots only (

Table 2), we see the use of residue incorporation rising again after the second year. The use of mineral fertiliser decreases over the years. This might be due to the fact that farmers take advantage of the impacts of fertiliser and therefore do not continue with it during the whole period.

When looking at the average over five years, we see that the planned use of manure and composting does not differ much from their real use in 1994/1995 (see Table 4). However, the planned use of mineral fertiliser is at least twice as high as in 1994/1995, while the percentage of plots on which residue incorporation or no technique is planned is much lower.

Planned technique choice does not always coincide with the technique farmers indicate as the best. This is especially the case for mineral fertiliser. Even though mineral fertiliser is planned more often than actually used, its planned use is much lower than it would be under the 'best' plan. Even under the 'best' plan, 7 percent of the plots are grown without using any fertilisation technique. These are plots cultivated by farmers who indicate fallow as the best technique, which means at the time of cultivation no other techniques will be used.

Table 1 Planned use of fertilising techniques under the 'actual' production plan (percentage of plots)

Technique used	'95/96	'96/97	'97/98	'98/99	'99/00	Average
no technique	45	40	30	27	26	34
fallow	1	13	27	32	34	20
mineral fertiliser	23	21	19	15	15	19
organic manure	11	12	10	11	11	11
residue inc.	13	7	7	8	7	9
composting	4	5	5	5	4	5
other	2	2	2	3	2	2
number of plots	(597)	(534)	(517)	(501)	(491)	(2,640)

Source: Survey VU-UNB 1995

Table 2 Planned use of fertilising techniques under the 'actual' production plan (Percentage of cultivated plots)

technique used in:	'95/96	'96/97	'97/98	'98/99	'99/00	average
no technique	46	45	41	39	39	43
fallow	-	-	-	-	-	-
mineral fertiliser	23	24	26	22	23	24
organic manure	11	14	13	16	17	14
residue inc.	13	8	10	11	11	11
composting	4	6	6	7	7	6
other	2	2	3	4	3	3
number of plots	(593)	(465)	(379)	(340)	(322)	(2,099)

Source: Survey VU-UNB 1995

Table 4 Technique choice under different production plans (percentage of plots)

	'actual' plan	'without' plan	'best' plan	real use*
no technique	34	77	7	44
Fallow	20	23	15	21
mineral fertiliser	19	-	48	9
organic manure	11	-	15	11
residue inc.	9	-	5	16
Composting	5	-	7	6
Other	2	-	4	4
number of plots	(2,640)	(2,616)	(2,602)	(3,061)

Note: Average over five years
* the actual technique use in 1994/1995.
Source: Survey VU-UNB 1995

The higher use of mineral fertiliser may also be a result of a selection bias; for one of the two plots we specifically asked for plots with either groundnut, cotton or tobacco on it. This means that cash-crop growing farmers have a higher probability of having two plots selected. Since the cultivation of cash crops, especially cotton, is closely related to the use of mineral fertiliser (see Table 10), the probability of finding a more widespread use of mineral fertiliser is higher. Similarly, only plots were selected that were cultivated in 1994, resulting in low numbers of planned fallow in the first years.

In Table 4 we have split the use of fertilising techniques for the two types of plots. Cash crop plots indeed show a much higher planned use of mineral fertiliser than food plots. For the former, farmers tend to use more composting instead of organic manure, whereas it is the reverse for food plots. Residue incorporation is used much more than twice as often on food plots than on cash crops plots. Food plots still show a higher planned use of mineral fertiliser than actually practised.

The interesting question is why some farmers do not use the technique they consider best for fertilisation. A likely reason is the cost. Before considering the costs of fertilising, we will discuss their benefits. In Table 4 we can already see one of these effects: an increased use of fertilising techniques allows fallow to be reduced, or the cropping period to be extended.

Table 4 Planned use of fertilising techniques on food plots and cash crop plots in percentages*

	food plots		**cash crop plots**	
no technique	34	(42)	35	(44)
fallow	20	-	22	-
mineral fertiliser	16	(20)	27	(34)
organic manure	14	(17)	3	(4)
residue inc.	10	(13)	5	(6)
composting	4	(5)	6	(8)
other	2	(3)	2	(3)
number of plots	1,867	(1,495)	773	(604)

Note: *Figures in parenthesis are percentages of plots in cultivation
Average over five years.
Source: Survey VU-UNB 1995

Extension of Cropping Period

One of the advantages of soil fertility management is the extension of the cropping period or a reduction of the fallow period. In Table 5 we see a large difference between the percentage of plots in fallow under the different production plans. The use of fallow is very low in the first year(s) in all production plans. This is a result of a selection bias, for which there are two reasons: firstly, only plots cultivated in 1994/1995 had a possibility of being included in the sample. This means the plots put to fallow in 1995/1996 were only one year old fallow. Second, we believe the questions were often not registered for plots that are put into fallow in 1995. Probably this non-response is the best explanation for the low rate of fallow in the first year(s).

Table 5 Percentage of plots in fallow under different production plans

Production plan:	’95/96	’96/97	’97/98	’98/99	’99/00	Average
Actual	1	13	27	32	34	20
Without	2	15	30	36	39	23
Best	1	8	16	24	30	15

Source: Survey VU-UNB 1995

The five year average of plots in fallow under the ‘actual’ production plan is not an unrealistic number. It is slightly higher than real average in the year 1994/1995 (see Table 4). For the ‘without’ production plan we would expect the use of fallow to be larger, because no other fertilising techniques are used. We can see in Table 5 that this is confirmed by the average number of plots in fallow which is higher in the ‘without’ plan. Another way of looking at this is to calculate the number of years the land is planned to be cultivated, and compare this with the number of years cultivated under the ‘without’ plan[4]. Because these two numbers are not independent, we take the difference between the two numbers for each farmer, and test whether the difference significantly differs from zero. In this way we can test whether the number of years in cultivation under the new production plan equals the number of years under the old production plan.

Taken over the whole sample (including the farmers whose production plan remains unchanged), the mean difference is small but significant and positive (see Table 6). This indicates that farmers in general plan to cultivate land for a shorter period of time when no fertilisation techniques are used other than fallow (comparison 1).

Table 6. Differences in years of cultivation under different production plans

	Mean	N	SE	t-value	Prob > |t|
1 actual – without	0.17	499	0.039	4.28	0.0001
2 best – actual	0.32	494	0.042	7.56	0.0001
3 best – without	0.49	491	0.052	9.41	0.0001

Note: Actual = years of cultivation under the ‘actual’ production plan
Without = years of cultivation under the production plan without innovations
Best = years of cultivation under the production plan with the best technique
Source: Survey VU-UNB 1995

[4] Both have a maximum of five years.

When we compare the ‘best’ production plan with the ‘actual’ production plan, the difference is positive and significant (comparison 2), and is larger than the difference between ‘actual’ and ‘without’ (comparison 1). This indicates that on average farmers are not maximising the number of years under cultivation in their ‘actual’ production plan. If farmers used the best fertilising technique they knew instead of using no technique (except fallow), they would on average cultivate half a year longer before putting their land to fallow (comparison 3).

Not all techniques result in equally long periods. When looking at the number of years gained by using the best technique compared to using only fallow, agroforestry is indicated by farmers as a technique that extends the cropping period most (see Table 7). However, this technique is not well known by many farmers. Parking and mineral fertiliser follow, not far apart and both highly significant. Farmers consider these good methods to extend the cropping period. Residue incorporation is not seen as a method that allows extension of the cropping period, since the mean is not significantly different from zero.

Table 7 Extra years of cultivation per technique

	Mean	N	t-value	Prob.t
Agroforestry	1.0833	12	2.2385	0.0468
Parking	0.6000	60	4.3164	0.0001
mineral fertiliser	0.5742	256	7.4618	0.0001
Composting	0.5128	39	2.4348	0.0197
Manuring	0.3571	28	2.5852	0.0155
residue inc.	0.2414	29	1.6532	0.1095

Source: Survey VU-UNB 1995

We can conclude that farmers are well aware that using fertiliser techniques allows extended cultivation of their land. Farmers consider fertilisation as a substitute for traditional fallow. However, not all techniques perform equally well. Agroforestry, parking, mineral fertiliser and composting seem to perform best in this respect.

Changes in Crop Choice

Soil fertility management generally allows a wider range of crops to be grown. To find out how crop choice alters with a change in techniques available to farmers, we asked farmers how their production plan would change if they changed their technique to fallow or 'the best' technique. In reality the causality between crop choice and technique choice will be, at least partly, the other way around. When farmers want to grow a certain crop, they will use an appropriate technique. In this section we discuss the link between crop choice and method. We will start with a description of how crop choice changes with soil fertility technique change. Subsequently we discuss why this combination of crop and technique is chosen by the farmer and whether changes in crop choice can explain changes in technique use.

Crop choice under different production plans

We want to know which crops will be grown when either more or less fertiliser is used. We can see this by looking at the crops that will be grown under the three production plans (see Table 8). However, we first want to compare the crops grown under the 'actual' plan with the crops grown over the 1992-1994 period (see Table 10). Although the two tables are not directly comparable because in Table 10 intercroppings are taken apart, we can see that crop choice under the 'actual' plan is not representative for the Atacora province in general. A more detailed study of the 'actual' plan revealed that under the 'actual' plan more intercropping, maize and cotton was planned than grown over the last three years, but much less sorghum, millet and yam. As we explained earlier, this is a result of a selection bias in the sample, which lead to the over-representation of cash crops and an under-representation of crops like yam.

Comparing the 'actual' and 'without' plan in Table 8, we see a shift from relatively new crops like maize and cotton towards the more traditional crops like sorghum, millet and cowpea when less fertiliser is used.

Table 8 Crop choice under the different production plans

	Crops grown under the actual production plan number of plots	(%)	Crops grown under the without production plan number of plots	(%)	Crops grown under the best production plan number of plots	(%)
Sorghum	733	(22.8)	739	(24.0)	737	(21.9)
Maize	632	(19.6)	565	(18.4)	701	(20.8)
Cowpea	443	(13.7)	453	(14.7)	447	(13.3)
Millet	311	(9.7)	328	(10.7)	301	(8.9)
Yam	235	(7.3)	242	(7.9)	243	(7.2)
Cotton	221	(6.9)	104	(3.4)	285	(8.5)
Groundnut	207	(6.4)	196	(6.4)	242	(7.2)
Cassava	160	(4.9)	164	(5.3)	164	(4.9)
Hungry rice	99	(3.1)	108	(3.5)	66	(2.0)
Other crops	180	(5.6)	175	(5.6)	184	(5.5)

Note: Percentages are column percentages. Fallow is not included. Plots may have been double counted due to multiple cropping

Source: Survey VU-UNB 1995

Under the ‘best’ production plan, we see a shift the other way - less traditional crops are grown and more cotton, maize and groundnut. When fertiliser is used, farmers tend to grow more cash crops. It is interesting to see that yam is not grown more often when fertiliser is used, since it is a very appreciated crop in the Atacora. The reason is that it is a crop grown at the beginning of a rotation cycle, and when the cropping period is extended, relatively fewer ‘leading’ crops will be grown.

When comparing the ‘actual’ and ‘without’ plans, we see that in percentage terms, the choice for traditional crops increases only slightly, whereas in absolute numbers the increase is even smaller. While under the ‘without’ plan 53 more cases of traditional crops are chosen, the choice for cotton and maize drops more than proportionally (in Table 8). Maize drops by 67 cases (11% less), and cotton drops by 117 cases (53% less). It appears that traditional crops are grown in roughly the same proportion under all plans. When fertiliser techniques are used, extra crops can be grown, due to a longer cropping period, and these crops are mainly cotton, maize and, to a lesser extent, groundnut.

In Table 10 we see that under the ‘actual’ plan some crops are more likely to be grown with certain fertilising techniques than others. An example is cotton, a crop nearly always grown with mineral fertiliser. Maize is another crop that is often grown with mineral or organic fertiliser. Not all crops respond equally well to certain types of fertiliser.

Farmers growing cotton have easy access to mineral fertiliser on credit. Some farmers will also use this fertiliser on crops other than cotton. In the Atacora, cotton farmers use mineral fertiliser more often on other crops than farmers who do not produce cotton. Cotton farmers applied mineral fertiliser to 12% of the non-cotton plots, of which the maize plots were fertilised most often with 30%. Non cotton-producing farmers apply mineral fertiliser to only 4% of their plots and 14% of their maize plots. Not only do cotton farmers use mineral fertiliser more often on maize, they grow more maize as well. Cotton farmers grow maize on 25% of their plots while other farmers have only 13% of their plots under maize.[5]

[5] Figures are for 1994

Table 10 Shares of techniques planned by crop choice under the 'actual' production plan (in percentages*)

	no technique used	residue inc.	com-posting	mineral fertiliser	organic manure	other	N
Sorghum	42	11	7	10	25	5	(733)
Maize	27	7	9	31	20	6	(633)
Cowpea	48	7	5	14	23	3	(443)
Millet	46	18	12	5	16	2	(311)
Yam	35	18	18	11	7	11	(234)
Cotton	2	0	0	97	0	0	(221)
Groundnut	42	13	7	21	11	6	(207)
Cassava	30	10	14	26	9	11	(160)
Hungry rice	76	13	0	4	7	0	(99)
Other crops	33	3	4	31	16	13	(180)
Average**	37	10	8	23	17	6	(3,221)

* Row percentages, averages over 5 years
** Differs from Table 1 due to intercropping and exclusion of fallow.
Note: Double counting of plots is possible due to intercropping
Source: Survey VU-UNB 1995

The production of cash crops is essential to be able to pay for the fertiliser. We have seen that under the 'best' plan the production of the cash crops cotton, maize and groundnuts increases. We have also seen that under the 'actual' plan, mineral fertiliser is used especially on cotton, maize and groundnuts. In the next section we discuss farmers' estimations of the effects of fertiliser on yields. We expect farmers to estimate large yield increases when using fertiliser on cotton, maize and groundnut compared to other crops. We will now try to answer whether the change in crop choice under the 'best' plan can sufficiently explain technique use under the 'best' plan.

Explaining technique use by crop choice

We can check to what extent crop choice explains technique choice by comparing the 'actual' and the 'best' plan. When techniques are chosen only on the basis of crop choice, we can predict technique choice in the 'best' plan on the basis of the 'actual' plan in Table 10. We multiply each row of Table 10 with the number of times the corresponding crop is grown under the 'best' plan to get an estimation of technique use under the 'best' plan. When technique choice depends very much on crop choice, the predicted technique choice will be close to the choice under the 'best' plan. Before comparing the numbers we have to correct for the increased number of crops grown under the 'best' plan due to extension of the cropping period.[6] The results are shown in Figure 3.

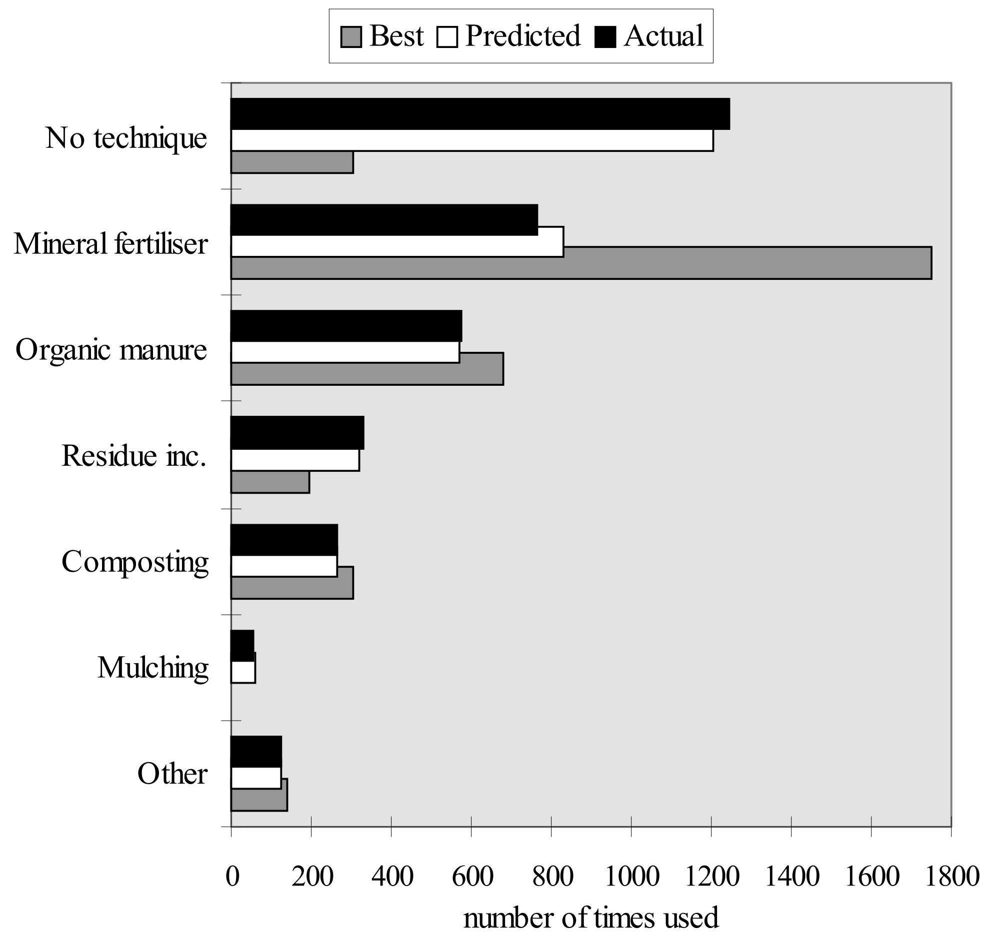
We can see from the figure that the predicted technique choice is in all cases closer to the 'actual' plan than to the 'best' plan. In order to test whether crop choice can sufficiently explain technique choice under the best plan we perform a χ^2 test of goodness of fit, comparing predicted technique choice with technique choice under the 'best' plan. With 6 degrees of freedom and a χ^2 of 1,828 the null-hypotheses needs to be rejected at the 0.05 level. This implies there is a significant difference between the planned and the predicted

[6] Without correcting for extended cropping period the conclusions are the same but slightly weaker.

technique choice and crop choice does not sufficiently explain technique choice under the 'best' plan.

Even when crop choice could explain the technique choice under the 'best' plan, the causality may be the other way around. The causality of the crop choice and technique choice is difficult to check, because we do not have information on decisions taken but only on planned behaviour of farmers. Even if we can show by means of causality tests that fertilising techniques are applied before the crop is planted, the decision to plant the crop may be taken before the decision to use a specific fertilisation technique. Fertilising certain crop naturally takes place before or during the season the crop is grown, for the simple reason that afterwards is not beneficial to yields of the preceding season.

In Figure 3 we see that the use of mineral fertiliser particularly is much higher under the 'best' plan than under the predicted plan. Under the 'actual' plan and in reality, mineral fertiliser is mainly used on cotton, maize and groundnuts. Under the 'best' plan, where mainly mineral fertiliser is used, we would expect farmers to plan to grow more of these three crops. However, crop choice under the best plan is more similar to crop choice under the 'actual' plan than we would expect on the basis of techniques chosen.



Source: Survey VU-UNB 1995

Figure 3 Predicted technique choice on the basis of crop choice

One constraint to farmers who do not grow more cash crops under the ‘best’ plan may be a problem of market integration. Farmers may be forced to grow certain crops that do not respond well to fertiliser for their own needs because these crops cannot be bought on the market, while other crops that give a high return to fertiliser cannot be sold on the market. This does not mean necessarily that it is not useful to fertilise these crops, simply that farmers will not grow more than household needs. One example is cotton, which is grown for the market only. The marketing board purchases cotton from Village Groups. However the board decides which villages to buy cotton from, so even if a Village Group is formed, this does not guarantee purchase by the board. Hence some farmers, particularly those with little access to markets, will chose not to grow cotton, even under the ‘best’ plan.

We can conclude from this section that soil fertility management permits a wider crop choice. This is reflected in a tendency towards growing more cotton and maize when fertilising techniques are planned, although this is not necessarily at the expense of traditional crops such as sorghum, millet, cowpea and hungry rice. Soil fertility management permits extra cropping seasons in the rotation, which benefit mainly cash crop production. Although the production of cotton, maize and groundnuts increases under the ‘best’ plan, this increase is not sufficient to explain the high use of mineral fertiliser under the plan. Under the ‘best’ plan the farmer will use mineral fertiliser on crops not fertilised under the ‘actual’ plan.

In order to obtain mineral fertiliser a farmer must grow cotton or another cash crop. Most mineral fertiliser is in turn allocated to cash crops. A possible reason is that cash crops happen to be crops that respond very well to mineral fertiliser use. In the next section we want to discuss farmers’ estimations of the effects of soil fertility management on yields. We hope to explain why mineral fertiliser is mainly used on cash crops. We expect farmers to estimate high yield increases when using fertiliser on cotton, maize and groundnut compared to other crops.

Soil Fertility and Yields

Crop yields benefit from soil fertility management in three ways. The first and immediate impact is the increase in crop yield; secondly, the rate of yield decrease is reduced; and finally the cropping period is extended so that yields can be obtained in years when previously no cultivation would take place. We will discuss farmers' estimations of these effects in turn and provide an indication of their accuracy by comparing them to the yields actually obtained.

Table 10 Prevalent crops in the Atacora-survey

Crop or intercropping	Number of crops	Number of plots	% of plots	Area (Ha)	Area %
Yam	1	1.057	(17)	748	(15)
Sorghum	1	776	(12)	653	(13)
Maize	1	714	(11)	625	(12)
Millet	1	497	(8)	392	(8)
Groundnut	1	473	(8)	366	(7)
Sorghum-Cowpea	2	456	(7)	446	(9)
Cassava	1	422	(7)	291	(6)
Cotton	1	405	(6)	543	(11)
Rice	1	359	(6)	171	(3)
Maize-Sorghum	2	287	(5)	340	(7)
Hungry Rice	1	264	(4)	189	(4)
Bambara Groundnut	1	210	(3)	91	(2)
Millet-Cowpea	2	198	(3)	160	(3)
Cowpea	1	138	(2)	111	(2)

Note: The figures are taken over the years 1992-1994.
Only intercroppings grown on more than 1% of the plots are shown.
Percentages in table are column percentages for the crops in the table only.
Source: Survey VU-UNB 1995

Several problems arise when comparing yields. First, yields of different crops are difficult to compare. We could use monetary values of production (physical quantity × price) instead. The main drawback of this approach is that food markets in the Atacora are poorly developed, which means that market prices received by farmers are poor indications of the 'true' value of the goods. Another option is to measure yields in calorific content, which is an option when mainly food crops are compared, but this is not the case here. We have chosen to compare only values or physical amounts.

Second, in the case of intercropping, yields of individual crops are difficult to calculate. It is tempting to consider intercroppings as a combination of several pure crops. Unfortunately, it is not known how the crops are distributed on a farmer's field and therefore it is impossible to calculate the exact yield for each of the crops. In the 1994/1995 survey as many as 113 different crops and intercroppings were found, though many of these were not very common. Only 14 crops and intercroppings were found on more than 1% of all plots, and together these accounted for 86% of all cultivated plots (see Table 10). The crops for the future production plans are somewhat different. The crops from Table 10 account for 76% of the crops planned to be grown by the farmers. However, just considering pure crops will already account for a large part of the plots in the Atacora (see Table 10). In the remainder of this paper we will generally look at pure crops. Intercroppings are included in the following two cases: When comparing physical yields, the most prevalent intercroppings (see Table 10) are included when yields of the same intercroppings are compared. Intercroppings are also included when values are compared instead of physical yields. Where there is deviation from this approach it will be explicitly stated.

Finally, farmers' estimations of yields sometimes show large outliers, which seriously influence the mean of the yield estimates. We therefore decided to use the median instead of the mean because it is less sensitive to outliers. As a test to check whether the median (of a difference) is significantly different from zero we used the nonparametric sign test in Table 12 through Table 18. In this test we test the probability of a greater absolute value for the sign statistic, testing the hypothesis that the median change in yields equals zero. The sign test was calculated from the differences between the two yield estimations in the following way:

Sign statistic = $p - n/2$

p is the number of differences greater than 0.
n is the number of nonzero differences.

Under the null hypothesis that the population median is zero, the probability of a sign statistic equal or greater than the observed value is:

$$P = 2\sum_{j=0}^{\min(p,n-p)} \binom{n}{j} 0.5^n$$

Comparison of production plans

When we calculate the median yield for each crop, we see that the yield estimates are quite reasonable (see Table 11). The medians of the actual yields obtained are generally somewhere between those under the 'without' plan and the 'actual' plan. As we expect to see, the following (in)equality holds and gives another indication that the yield estimates are realistic:

Yield 'without' ≤ Yield 'actual' ≤ Yield 'best'

Table 11 Median estimated yields for pure crops under different production plans

	Yield 1995/96 'actual' plan		Yield 1995/96 'without' plan		Yield 1995/96 'best' plan		Yield actually obtained*	
	Median	N	Median	N	Median	N	Median	N
Sorghum	800	39	733	53	900	22	667	216
Maize	1,000	60	900	58	1,267	74	1,000	224
Cowpea	500	5	483	8	667	3	600	13
Millet	600	19	600	21	775	10	490	120
Yam	6,250	16	3,750	17	8,000	15	9,000	235
Cotton	1,500	55	750	20	1,500	67	1,200	203
Groundnut	800	32	640	30	1,000	35	673	184
Cassava	11,850	10	4,875	4	-	-	2,175	70
Hungry Rice	270	20	270	21	270	9	360	74

* Median over those plots for which the plans were asked, over three years.
Source: Survey VU-UNB 1995

Another way to compare differences between expected yields under different production plans is to see whether the yield estimates given by farmers are significantly different. The results are presented in Table 12 for several crops. Differences in yields are only calculated when the corresponding crops or intercroppings are identical. The comparison between the 'best' and the 'without' plan in the second column is particularly interesting. We see that median differences in expected yields are always positive and significant.[7] Median expected yields increase slightly over the years when fertiliser is used

The comparison between other plans is sometimes difficult to interpret. There is a selection bias in these comparisons. Only those plots that have the same crops grown under the two plans in the particular year are selected. When farmers use the same fertilising techniques under the compared plans, crop choice is more likely to be the same. For example, a farmer who is not planning to use any fertiliser under the 'actual' plan, is likely to grow the same crops under the 'without' plan and will be selected for the analysis. Similarly, a farmer who grows cotton using mineral fertiliser under the 'actual' plan, is more likely to grow another crop under the 'without' plan because no mineral fertiliser can be used. In this case the farmer will not be selected for the analysis. The results of the last two columns are therefore biased downwards and not very useful.

[7] Except the yield difference for hungry rice in 1999/2000, which is significant at the 10% level only.

Table 12 Differences in expected yields between different production plans (Median of difference %)

		Best-Without			Actual-Without			Best-Actual		
		Median	**Sign.**	**N**	**Median**	**Sign.**	**N**	**Median**	**Sign.**	**N**
Sorghum	‘95/96	67	**	113	0	**	159	20	**	130
	‘99/00	67	**	52	27	**	62	0	**	72
Maize	‘95/96	52	**	94	17	**	117	0	**	128
	‘99/00	58	**	42	50	**	48	0	**	67
Cowpea	‘95/96	71	**	59	0	**	87	20	**	71
	‘99/00	108	**	30	0	**	42	33	**	43
Millet	‘95/96	94	**	36	0	**	67	24	**	40
	‘99/00	50	**	17	0	**	22	10	-	23
Yam	‘95/96	47	**	29	0	**	34	20	**	31
	‘99/00	33	**	29	13	**	28	0	-	27
Cotton	‘95/96	117	**	20	100	**	19	0	-	49
	‘99/00	175	**	12	175	**	12	0	-	27
Ground-nuts	‘95/96	52	**	34	12	**	38	10	**	43
	‘99/00	105	**	12	24	**	14	11	**	15
Cassava	‘95/96	39	**	16	5	**	22	5	**	19
	‘99/00	38	**	12	25	**	13	0	**	16
Hungry rice	‘95/96	50	**	8	0	-	20	33	*	8
	‘99/00	133	*	6	0	**	14	50	-	9

Notes: Calculated as the median of the difference in %:
Best - Without = ((‘best’ yield - ‘without’ yield) / ‘without’ yield) × 100
Sign. = significance sign statistic = Probability of a greater absolute value for the sign statistic, testing the hypothesis that the Median change in yields equals zero.
** Significant at the 5% level, * Significant at the 10% level, - Not significant at the 10% level.
Source: Survey VU-UNB 1995

The fact that cotton does not show a significant difference in expected yield between the ‘best’ and the ‘actual’ plan could also indicate that for cotton, farmers’ actual behaviour is close to best. The same may be said for maize although there still is a significant difference. We can say that farmers are very much aware of the benefits of soil fertility management terms of receiving higher yields.

Comparison of soil fertility regimes

It would be interesting to see how farmers estimate the yield increases for individual soil fertility regimes. However, disaggregating into crops *and* techniques would result in very low numbers of observations per cell. Therefore we take crops together and calculate yield differences in percentages. Yields are compared between the ‘best’ plan and the ‘without’ plan for those plots that have the same crops under both plans in the particular year. Percentage yield increases were calculated and the medians of these percentages are presented in Table 13. Improved and ordinary fallow are not included in the table because no yield increases can be calculated when land is fallow.

It is interesting to see that although mineral fertiliser was the most frequent indicated best technique, it does not show the largest expected yield increase within one and five years.

Although parking and agroforestry show much higher improvements of yield vis à vis production without fertilising, not all farmers think these techniques are the 'best'. We must take into account that the estimates for agroforestry and parking come from a different sample of farmers. Not all farmers are aware of agroforestry or parking. Additionally, yield increases may not be the only criterion farmers take into account when selecting a 'best' technique, since crop choice and extension of the cropping period will also be considered.

From this table it is not very clear what the effect of fertilisation on yields are in the medium term. As we have said before, comparison on the basis of this table is difficult because the plots compared are not the same. When we compare expected yields over time, we would expect yields to decrease after some years of cultivation, unless sufficient fertilisation is used. Farmers' estimates of this drop in yield are discussed next.

Table 13 Expected yield increase by consistent use of techniques (in %)

	Year	Median	N	Sign Stat.	Prob. S.	Mode
Agroforestry	1995	200	12	6.0	0.00049	100
	1999	192	6	3.0	0.03125	117
Parking	1995	88	59	24.5	0.00000	100
	1999	100	33	15.5	0.00000	100
Mineral fert.	1995	60	232	94.0	0.00000	100
	1999	79	124	53.5	0.00000	100
Manuring	1995	50	22	6.5	0.00235	0
	1999	67	11	4.5	0.01172	67
Residue inc.	1995	57	33	14.5	0.00000	0
	1999	58	17	7.5	0.00027	100
Composting	1995	50	46	20.0	0.00000	50
	1999	50	27	11.5	0.00001	50

Note: Median of the percentages calculated as: (('best' yield - 'without' yield)/'without' yield)×100
Source: Survey VU-UNB 1995

Effects over the years

Before turning to the effects in the medium term we will discuss farmers' estimates of yields when repeating the crop a second time. For millet, yam and groundnut farmers estimate a decrease in yield when growing the crop a second time around, using the same techniques as used last year (see Table 14).

The reason for a yield decrease when growing a crop a second time around is a reduction in soil fertility. This reduction results not only from an *extra year* of cultivation, but also from growing the *same* crop again. For maize and sorghum intercropped with cowpea there is no clear yield decline, except for sorghum intercropped with cowpea. Cotton yields even increase after one year according to farmers. Farmers may well realise well the (after-)effects of fertiliser used with cotton, and in reality farmers often do grow cotton on two or more consecutive years.

Table 14 Estimated yield differences when growing the same crop again, using the same technique (in percentages)

	N	Median	Sign stat.	Crop
Pure crops				
Sorghum	31	0	-	
Maize	55	0	-	
Millet	16	-26	*	
Yam	25	-17	**	
Cotton	62	+ 2	**	
Groundnut	51	-14	**	
Intercroppings				
Maize-Sorghum	20	0	-	Maize
		0	-	Sorghum
Sorghum- Cowpea	26	-8	**	Sorghum
		0	-	Cowpea

Note: Median of the percentages calculated as: ((yield 99/00 - yield 95/96)/yield 95/96)×100
Results are reported when N>10
- Not significant
* Significant at the 10% level
** Significant at the 5% level
Source: Survey VU-UNB 1995

In the Atacora, on average over the three year period 1992 to 1994, as much as 35% of the plots carried at least one crop which was the same as the previous year[8]. Only 15% of all cultivated plots had exactly the same crop or intercropping two years in a row. However, we have to take into account how often the crop is cultivated in the first place. When a crop is cultivated often, it is more likely to be grown in two consecutive years. We therefore calculate the following crop repetition ratio, for example for maize:

$$\frac{\text{number of plots with maize in 1993 } \textit{and} \text{ 1994 / plots with maize in 1994}}{\text{number of plots with maize in 1994 / total plots cultivated in 1994}}$$

When maize is grown equally often after maize than after any other crop, this ratio would be 1. When the ratio is higher, the crop is repeated more often. We have calculated the ratios including all intercroppings of the crops (Table 15, column: Intercroppings). This means that for example a plot with maize-cowpea following a maize-sorghum intercropping counts as a repeated crop. We have also calculated the ratio for the main crops when exactly the same crop or intercropping was grown on a plot (Table 15 column: Pure crop).

Yam shows the lowest repetition ratio, followed by sorghum and groundnut. Farmers avoid repeating these crops because they estimate it will negatively affect yields. From Table 14 we can see a significant estimated yield decline for these crops. For sorghum there is no significant yield decline except when associated to cowpea. Millet and maize show similar repetition ratios, not very high. However, the millet yield decline is estimated to be larger than the maize yield decline.

[8] Considering only those plots that were cultivated two years in a row.

Table 15 Crop repetition ratios for 1992-1994

	Intercroppings	Pure crop
Rice	11.7	14.7
Sorghum	1.3	1.3
Millet	1.9	2.2
yam	0.9	1.1
cassava	4.3	5.0
cowpea	3.7	6.9
groundnut	1.6	1.7
cotton	7.2	7.1
sorghum-cowpea		6.0
maize-sorghum		7.9

Source: Survey VU-UNB 1995

For cotton the ratio is much higher than the average, indicating cotton is often grown over two or more consecutive years. We can see from Table 14 that farmers think that repeating cotton has a significant positive effect on cotton yields. Intercropping sorghum with cowpea and maize with sorghum is often repeated as well. Farmers estimate no significant yield decline for these crops, and only a small but significant yield decline for sorghum when associated to cowpea. Rice is the crop most often repeated on the same plot. The reason is that rice is typically grown on river banks, where not many other crops are grown. Unfortunately we do not have enough observations to give estimations of expected yield differences for rice.

We have compared yields when a crop is grown in two consecutive years. Now we want to show how farmers estimate yield changes over a period of five years. We can only compare the 1995/96 yields with the 1999/00 yields, when the same crops are grown in the two years. The resulting differences in percentages between the 1999/2000 yields and the1995/96 yields for those plots that have the same crop (or intercropping) in both years, are presented in Table 16 and Table 17. We would expect the following:

difference 'without' ≤ difference 'actual' ≤ difference 'best'

and: **difference 'without' < 0**

The difference under the 'without' plan should have a negative sign, because soil fertility should decrease fertilising methods are used. The difference under the 'best' plan can very well be positive, when farmers expect that using the best technique will increase soil fertility over time, even when cultivated all five years. The difference under the 'actual' plan will depend on what techniques the farmer is planning to use, but the result should be somewhere between the other two.

When no method is used other than fallow, farmers expect yields to drop over five years. The median value of the yield decline is 14.5 % for those cases (see Table 16). For the other two plans the median yield decline is zero, but when we look at the other percentages the 'best' plan performs best in maintaining yields.

Table 16 Differences in estimated yield over five years in percentages

	Median	N	Sign stat.	Prob. S.	Q25%	Q75%
'without'	-14.5	154	-33	0.0001	0	-40
'actual'	0.0	199	-17	0.0029	0	-25
'best'	0.0	198	-15	0.0073	0	0

Note: Median of the percentages calculated as: ((yield 99/00 - yield 95/96)/yield 95/96)×100
Source: Survey VU-UNB 1995

In Table 17, the median differences for all crops satisfy the inequalities. Under the 'without' plan we always see a large and significant yield decline.[9] Under the 'best' plan no significant yield decline can be found for pure crops. The results for cotton under the 'without' plan are not shown because of the low number of observations on cotton under the 'without' plan. Again we see that farmers are very much aware that yields will drop over the years when no fertiliser is used. Farmers clearly see the medium and long-term effects of using fertiliser and realise that it is needed to maintain yields. At the same time farmers do not expect yields to decline very much under the actual plan. Apparently farmers plan to use fertiliser in such a way that yield declines are close to zero.

[9] Except the yield decline for millet is not significant.

Table 17 Differences in estimated yield over five years in percentages (separate crops)

	Median	N	Sign stat.	Prob. S.	Q25%	Q75%
Sorghum						
Actual	0	53	-3.5	0.32401	-22	7
Without	-23	43	-12.5	0.00001	-40	0
Best	0	53	-5.0	0.13250	-20	0
Maize						
Actual	0	44	-3.5	0.24779	-17	0
Without	-5	31	-6.0	0.01182	-25	0
Best	0	43	-4.5	0.12208	-20	0
Cowpea						
Actual	0	38	-4.0	0.13380	-33	0
Without	-21	32	-5.5	0.03469	-50	0
Best	0	34	-3.0	0.23788	-33	0
Millet						
Actual	0	14	-1.5	0.50781	-33	0
Without	-33	11	-2.0	0.28906	-50	0
Best	0	13	1.0	0.68750	0	10
Cotton						
Actual	0	17	-3.0	0.10938	-25	0
Best	0	26	-1.5	0.58105	-20	0

Note: Median of the percentages calculated as: ((yield 99/00 - yield 95/96)/yield 95/96)×100
Results are reported as long as N>10
Source: Survey VU-UNB 1995

Table 18 Differences in expected yield from 'best plan' over five years in percentages (by technique)

	Median	N	Sign stat.	Prob. S.	Q25%	Q75%
Mineral fertiliser	0.0	79	-9.0	0.0154	-17	0
Parking	-5.7	32	-3.0	0.2379	-40	11
Manuring	0.0	11	-1.5	0.4531	-23	0
Composting	0.0	7	0.5	1.0000	0	33
No technique*	-14.5	154	-33	0.0001	-40	0

Note: Median of the percentages calculated as:
((yield 'best' 99/00 - yield 'best' 95/96)/yield 'best' 95/96)×100
* Taken from Table 16
Source: Survey VU-UNB 1995

In Table 18 we present median values of expected yield decline over five years for different techniques. For parking, manuring and composting the expected yield decline is not significant. Mineral fertiliser shows a significant but small expected yield decline. Comparing the individual techniques to no fertiliser again shows that farmers know yields will drop when no fertiliser is used.

We can conclude from this section that farmers not only realise yields are much lower without fertiliser, but also that yields will decline significantly over time when no fertiliser is used other than fallow. This also means that the planned use of fallow is not sufficient to maintain yields. The effects of fertilising methods on yields over time are well understood. In the 'actual' plan, the yield decline is not very different from zero for most crops. Farmers plan to use fertiliser in such a way that yield decline is avoided, although much higher yields are expected from intensive use. Although mineral fertiliser is most frequently indicated as the best technique, some farmers expect the highest yield increases from agroforestry and parking. Mineral fertiliser allows more valuable crops to be grown. In the following section we study the effects of soil fertility techniques on production in monetary values.

Values of Crop Yields

This section examines the impact of different techniques on expected yields, and the most valuable combination of crop and technique choice, according to farmers. We expect mineral fertiliser to be ranked the best, especially in combination with cotton, maize and groundnut production. We construct a model to explain farmers' yield estimates, using an OLS-regression on a fixed effects model at plot level with two classes of variables: crop choice and technique, and their cross-terms. To do the regression for several crops together, we used yields multiplied with prices in FCFA as the dependent variable (FCFA 100 = 1 French Franc). The regression was applied to the log of the yield to be able to interpret the results more easily in relative terms. The results are presented in Table 19.

No prices were available for some crops because no sales were recorded, and no price information was available at the CARDER. These crops were not selected for the analysis. Prices used in the calculations may be found in the Annex. We used 1994 prices, assuming farmers based their expectations on the prices of the season preceding the survey. The crops or intercroppings of Table 10 are used in the analysis, except rice, hungry rice, cassava, bambara groundnut and pure cowpea because of the low frequency of observations. Yam was not included in the analysis because it is considered a non-tradable. Yam is a very bulky crop, which means transport costs are very high. In addition it is perishable and often not transformed into a less perishable form, such as *gari* from cassava. This means it is very difficult for farmers to market yam.

In the calculations, only the 'without' plan and the 'best' plan were used because under these plans a technique is used over a longer period. The techniques were not always used on all intercroppings. This means there are missing cells in the analysis. Some techniques were used very infrequently. This makes hypothesis testing more difficult because of the low number of observations. Because not all techniques were equally important and to make the analysis more powerful, some techniques were regrouped. Parking and using animal manure are not identical techniques, but they are similar and therefore grouped together in the analysis. The most important technique, mineral fertiliser, is treated as a separate category. The remaining techniques are grouped together in the category 'other'. These three categories can be compared to the 'without' plan in the final category 'no technique' or 'none'.

We have the following specification with nine (i) crops and four (j) techniques:

$$\ln(\text{Yield in FCFA}) = \beta_1 + \beta_{2i}\text{crop}_i + \beta_{3j}\text{technique}_j + \beta_{4ij}\text{crop}_i \times \text{technique}_j$$

All independent variables are dummy variables. To avoid perfect collinearity, which means there is an exact relationship among the independent variables, we have to drop one dummy variable for each category. For example, we have to drop one crop from the category 'crops', otherwise the dummy variables of all crops together would always add to one. The dummies for maize and 'no fertiliser' were dropped, together with all the cross-terms that includes either one. This means the results of the regression are relative to the maize-no fertiliser case (see Table 19). The yield estimates used in the analysis were taken at two points in time, 1995 and 2000. No time dummy was used in the regression.

The intercept includes the main effects of pure maize and the effect of no fertiliser and its cross-effect. All other parameters are relative to the expected maize yield without fertiliser, which is on average $e^{10.758}$ = FCFA 47,025 for one hectare. The fourth column (e^{β}) indicates with what factor the intercept should be multiplied to account for the effect in the first column. For example, using mineral fertiliser on maize increases expected yields by a factor $e^{0.461}$= 1.59, an increase of 59 percent. From the third column we can see that this increase is significant.

Similarly, the production of sorghum with manure would mean an increase of the expected yield of a factor $e^{(0.552 - 0.040 - 0.195)}$ = 1.373, which would give an expected yield of FCFA 64,565. In this way we can calculate the yield estimates of all crop-technique combinations. These yield estimates are reported in the last column. The first four lines of the table refer to the four techniques in combination with maize. The following seven lines refer to the other crops, all without fertiliser.

At first glance the effect of mineral fertiliser seems lower than the effect of using manure, because the parameter for mineral fertiliser is lower. However, these parameters refer to the use of the technique in combination with maize only. The cross-effects of mineral fertiliser with the other crops are higher than the cross-effects of manure, except for millet. Cotton with mineral fertiliser gives the highest expected yield.

When we calculate for each crop the average of the expected yields under the different techniques, cotton gives the highest expected yield, followed by intercropping; millet with cowpea has a particularly high return per hectare. Because each crop responds differently to a technique, we cannot say one technique is best for all crops. We can compare techniques by calculating a weighted average of the expected yields for each technique when only that technique is used on each plot in the analysis. For mineral fertiliser this would amount to FCFA 104,199 per hectare. The averages for manure and other techniques are slightly lower with FCFA 89,739 and 92,601 respectively. Using no fertiliser at all results in a much lower expected yield of FCFA 57,309 per hectare.

Mineral fertiliser has the highest expected returns per hectare for cotton, groundnut and sorghum. Since cotton has a very high expected benefit per hectare, the average for mineral fertiliser comes out best. Manure gives the highest returns for maize, millet and sorghum & cowpea though these tend to be crops with a much lower average expected yield. The category ‘other techniques’ includes several other techniques. The actual technique used may differ per crop and this category is therefore difficult to interpret. Other techniques give the highest return for only two crops, ie, maize & sorghum and millet & cowpea. The latter shows a very large expected return per hectare on average, that is why ‘other techniques’ gives a higher average result than manure.

Mineral fertiliser results in the highest expected yields, which is not surprising given the fact that mineral fertiliser is most often indicated as the best technique. However, the price for mineral fertiliser has not yet been subtracted from this expected yield. Prices of mineral fertiliser were FCFA 9,500 for 50 kg on credit and FCFA 8,500 for 50 kg paid cash in the Atacora during the 1994/95 season. Since credit for fertiliser is almost exclusively available for cotton, we use the price of FCFA 8,500. Cheaper fertiliser, often of an inferior quality, can sometimes be bought on the parallel market. Even when we apply the recommended dose of 200 kg per hectare, the benefits outweigh the extra costs of using fertiliser (FCFA 34,000).

The efficiency point where marginal fertiliser costs equal marginal benefits cannot be calculated in this analysis, because quantities of fertiliser were not specified.

Table 19 OLS regression of ln (expected yield in FCFA)

Dependent variable: ln (yield in FCFA)	β	signif.	e^{β}	Yield estimate in FCFA
intercept (maize without fertilisation)	10.758	***	47,025	47,025
manure	0.552	***	1.74	81,666
other	0.393		1.48	69,643
mineralfert	0.461	***	1.59	74,541
maize & sorghum	0.300	***	1.35	63,509
sorghum	-0.040		0.96	45,173
sorghum & cowpea	0.268	***	1.31	61,489
millet	-0.208	*	0.81	38,201
millet & cowpea	-0.016		0.98	46,554
groundnut	0.027		1.03	48,292
cotton	0.671	***	1.96	92,023
maize & sorghum × mineralfert	-0.020		0.98	98,653
sorghum × mineralfert	0.121		1.13	80,787
sorghum & cowpea × mineralfert	0.037		1.04	101,071
millet × mineralfert	-0.231		0.79	48,071
millet & cowpea × mineralfert	0.280		1.32	97,085
groundnut × mineralfert	0.275		1.32	100,747
cotton × mineralfert	0.320	**	1.38	200,841
maize & sorghum × manure	-0.193		0.82	90,966
sorghum × manure	-0.195		0.82	64,552
sorghum & cowpea × manure	-0.040		0.96	102,497
millet × manure	0.515		1.67	111,000
millet & cowpea × manure	-0.169		0.84	67,903
groundnut × manure	-0.223		0.80	67,109
cotton × manure	-0.259		0.77	123,329
maize & sorghum × other	0.057		1.06	99,607
sorghum × other	-0.420		0.66	44,028
sorghum & cowpea × other	-0.247		0.78	71,096
millet × other	0.054		1.06	59,697
millet & cowpea × other	1.048	*	2.85	195,605
groundnut × other	-0.054		0.95	67,739
cotton × other	0.213		1.24	168,653
DF model 31	F-value = 15.175		significance F = 0.0001	
error 841				
total 872	Adj. R^2 = 0.335			

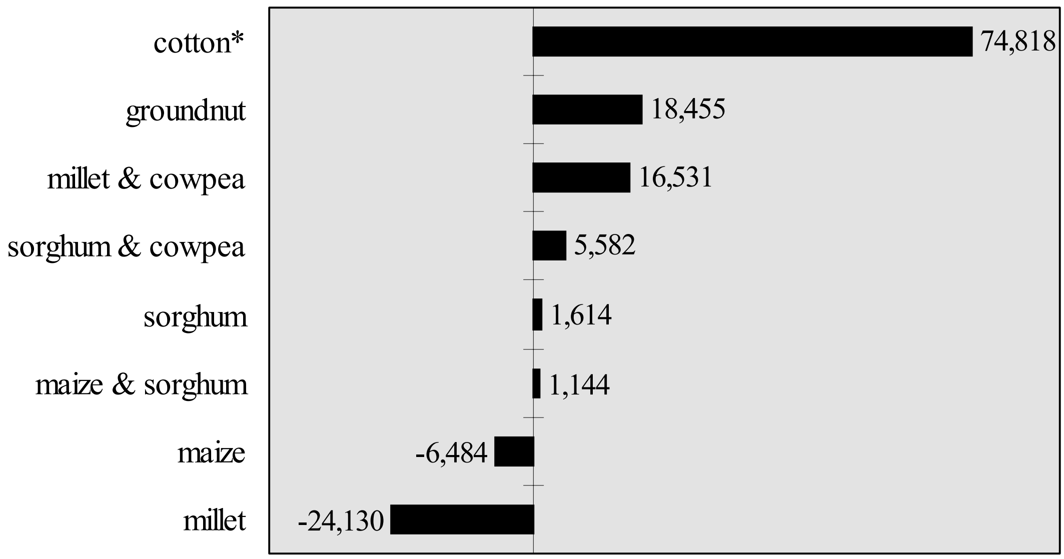
Notes: *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level
Source: Survey VU-UNB 1995

These expected yield figures are an average of all the observations in the analysis, which includes observations from the ‘best’ plan and the ‘without’ plan. We have seen that crop choice is biased in the analysis. We could recalculate the weighted average of the expected yield using as weights the number of times each crop is grown in the 1992-1994 season. Using the crop choice figures as weights to calculate the average expected yield, we get an average of FCFA 53,392 per hectare when no fertiliser is used and FCFA 95,224 - 34,000 = 61,224 when mineral fertiliser is used. According to farmers’ expectations the use of mineral fertiliser is profitable on average, when labour costs are not taken into account. We have not even corrected for changes in crop choice when other fertilising techniques are used.

Now consider the individual crops. When we compare the expected yield without using fertiliser with the expected yield using mineral fertiliser for each crop, and we subtract the fertiliser cost from the difference we get the net returns without taking into account labour costs. In Figure 4 the results are presented in order of magnitude.

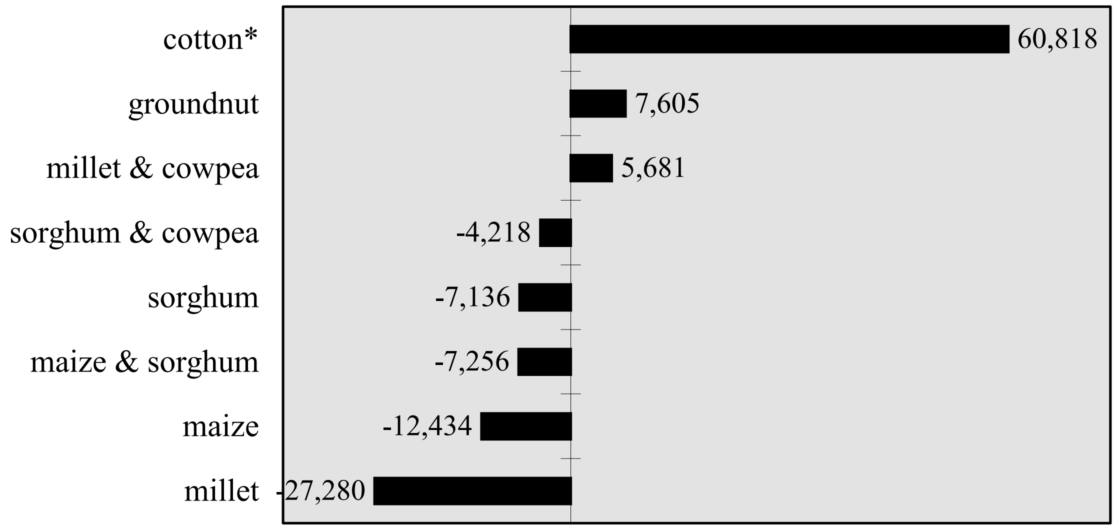
We would expect the crops on which fertiliser is most often used to be high up in the table. For cotton and groundnut this is clearly the case. However, maize is also a crop on which fertiliser is often used and maize comes out at the bottom of the table with millet.

Adding labour costs does not change this conclusion very much. Data on labour costs are available only from the VU-UNB 1995 survey in the centre zone (see Figure 1). The application of mineral fertiliser costs about 5 days per hectare. We can assume that all other labour costs remain unchanged, except at harvesting time, which will increase proportionally with yields. Fertiliser is applied outside the peak labour season, and shadow prices for labour can be very low for these activities.



Note: * fertiliser for cotton is usually bought on credit, which reduces net benefits by 4,000 FCFA
Source: Survey VU-UNB 1995

Figure 4 Net benefits from using mineral fertiliser in FCFA per hectare



Note: * fertiliser for cotton is usually bought on credit, which reduces net benefits with 4,000 FCFA
Source: Survey VU-UNB 1995, Survey VU-UNB 1996

Figure 5 Net benefits from using 200 kg mineral fertiliser in FCFA per hectare (including labour costs and mineral fertiliser costs).

Hired or invited labour was *never* used for applying fertiliser, and seldom for harvesting. However we use the median payment in kind for harvesting activities as an indication of the labour costs per day for these activities - FCFA 350 per man-day[10]. We have calculated for each crop the average number of harvesting days per hectare when using no fertiliser and the average number of harvest and fertiliser days when using mineral fertiliser. When the difference is multiplied by the costs per man-day and subtracted from the net benefit in Figure 4, we arrive at the net benefits including labour costs in Figure 5. The conclusions do not change significantly, although more crops have negative net benefits from using mineral fertiliser.

When farmers were not constrained by cash, they would use mineral fertiliser on all plots with cotton, groundnut and millet with cowpea (see Figure 5). However, in our survey we see that farmers almost uniquely use mineral fertiliser on cotton, maize and groundnut, the three cash crops. Mineral fertiliser use on cotton and groundnut is expected, but its use on maize is not straightforward. At the same time mineral fertiliser is hardly ever used on millet intercropped with cowpea, even though farmers do expect positive net benefits from using it.

Mineral fertiliser, a very costly input for farmers, requires cash income. When the farmer does not have an off-farm job and there are no remittances, the farmer has to grow cash crops in order to pay for mineral fertiliser. However, this cannot explain the farmers' choice to fertilise maize. Even when a farmer grows maize to get access to mineral fertiliser, from Figure 4 and Figure 5 we might conclude that it is not the best option. The farmer is better off applying the

[10] Invited labour is not as productive as family labour. This means that the costs for invited labour would actually be 1.5 times higher. However, since invited labour is hardly ever used for these activities, we use this price to indicate the payment the worker would have received when working elsewhere.

mineral fertiliser to millet intercropped with cowpea, even though this is not sold at the market. Land and labour saved this way can be allocated to the cash crops resulting in an even higher (cash) income.

One explanation is that prices used in the analysis are market prices that may be different from the prices faced by the farmer or the shadow-prices. Not all farmers in the Atacora have good access to markets. The majority are subsistence farmers producing for their own consumption. The value of a crop for a farmer or the shadow-price may be different from the market price. Small quantities of crops are sold on the market, especially by women, because some cash is needed. Cotton is generally grown in areas where roads are better and as a result access to markets is better. We have seen that cotton farmers are more likely to grow maize, and at the same time use much more mineral fertiliser, also on crops other than cotton. It is possible that the shadow price for mineral fertiliser is much higher for farmers who do not produce cotton.

At the same time the shadow price of maize may be much higher than the market price. For food security reasons maize is a very important crop in the Atacora, especially in the lean season. In the more remote areas where access to markets is difficult, farmers are dependent on their own production and for this reason the shadow price of maize may be much higher, prompting farmers to grow maize with mineral fertiliser.

Another reason may be that the results for maize are biased downwards. Farmers often indicated that on certain fields, growing maize without fertiliser would give such bad results that it would not be worthwhile, but sorghum or millet could still be grown without mineral fertiliser. This is confirmed by the results in Section 6. Here we see that under the best plan 24% more maize is grown than under the without plan. Probably, the yield estimates from the ‘without’ plan are biased because maize will only be grown on the more fertile plots and yields are biased upwards, whereas under the ‘best’ plan maize is also grown on less fertile plots. This bias is found when crops are grown under the best plan where they are not grown under the without plan. This is the case only for cotton, groundnut and maize. When using fertiliser implies that maize can be grown on a plot that would otherwise be fallow, the net benefits are very different.

In general we have seen that farmers expect mineral fertiliser to have a big impact on yields but at the same time the *net* benefits of mineral fertiliser are often very low or negative. Apparently, for many crops the high costs of mineral fertiliser and labour hardly outweigh the benefits. Taking this into account it is not surprising that of all farmers in the survey who have knowledge of mineral fertiliser (507), 53% say they do not use it (any more) because of lack of money.

Mineral fertiliser is often used on maize, whereas the expected net benefits are negative. Most likely the shadow price of maize is higher than the market price because maize is such an important crop in the lean season. For food security reasons the farmer is willing to pay for mineral fertiliser for maize even though at market prices net benefits would be negative. At the same time, the effect of mineral fertiliser use on expected maize yields is probably underestimated because of the selection bias in the results. On some plots maize yields would be so low without using mineral fertiliser, that maize is not grown at all on these plots.

Conclusions

In this paper we used a forward planning approach over a period of five years to study farmers' perceptions of the benefits of fertiliser. We compared farmers' actual plans and yield estimates with those under no soil fertility regime other than fallow and those considered to be the 'best'. All yields that were used in the calculations were estimated by farmers. Actual yields were used only as a check.

Farmers are well aware of the three benefits of soil fertility management: an increased cropping period, increased yields and a larger crop choice. Farmers estimate that intensive use of the best fertilising method they know, which for the majority of farmers is mineral fertiliser, allows the land to be cultivated on average half a year longer than the traditional fallow (taken over a five year period). The farmers who think agroforestry is the best technique expect the longest cultivation period, followed by those who have chosen parking and mineral fertiliser. The expected increase in cultivation period by using residue incorporation was insignificant.

When no fertiliser is used other than fallow, farmers expect yields to drop substantially over a five year period. The median decline in expected yield was 14.5% over the period. For some crops, like sorghum, millet and cowpea, the expected yield decline was even greater. This means that farmers do realise that fallow is no longer sufficient to maintain yields. Farmers expect yield decline over five years to be lower with the use of fertiliser. Calculated for the individual crops, farmers do not expect a significant yield decline over the coming five years if they used the 'best' techniques. When looking at the expected yields per technique, farmers who would use parking, manuring and composting as the best technique do not expect a significant yield decline over five years when these techniques are used each time the plot is cultivated. The yields estimated by farmers who consider mineral fertiliser to be the 'best' technique show a significant decline although the median is zero. From their actual plans for the coming five years they expect a very small and often insignificant yield decline for most crops.

Farmers recognise that not all crops respond equally well to fertiliser inputs. The expected effects on yields compared to no fertiliser are largest for cotton. Farmers expect yield increases of more than 100% and after 5 years even 175%. According to farmers' expectations maize does not perform well with fertiliser, with expected increases in yields lower than cassava and yam.

The decision about what crop to grow and what technique to use are not independently taken by the farmer. If only fallow were used, farmers would grow more traditional crops such as sorghum, millet, hungry rice and cowpea. If farmers could apply the 'best' technique, the cropping period would extend and used to grow more cotton, maize and groundnut.

When we look at benefits in FCFA per hectare and we compare only the most widely known techniques - mineral fertiliser, animal manure and natural fallow - farmers expect mineral fertiliser to generate the highest benefits in FCFA per hectare. The expected net return on using mineral fertiliser depends on the crop grown. Farmers expect mineral fertiliser to give a high net return on cotton, a crop on which it is always used. Surprisingly, the average expected net returns from using mineral fertiliser on maize are negative, whereas maize often receives mineral fertiliser. The most likely explanation is that, because it is such an important food crop especially during scarcity, the shadow price for maize is much higher than the market prices. At the same time, the effect of mineral fertiliser use on expected maize yields is likely to be underestimated because of the selection bias in the results. On some plots maize yields would be so low without using mineral fertiliser, that maize is not grown on these plots at all.

We have seen that in general farmers expect mineral fertiliser to have a great impact on yields but at the same time they expect that the *net* benefits of mineral fertiliser will be very low or even negative. Apparently, for many crops farmers expect that the high costs of mineral fertiliser and the extra labour do not outweigh the benefits.

When looking at farmers' planned technique use for the coming five years, we can say they plan to employ more techniques than in the previous years. This may be due to difficulties realising their plans, or to a growing awareness of the usefulness of these techniques. In reality farmers still rely very much on natural fallow and their plans have greater resemblance to the situation without fertilising than the situation with intensive fertilising. Farmers plan to fertilise enough to stabilise yields over the coming five years. Efforts to improve soil fertility management would not only result in increased yields; the extended cropping period could be used to grow more 'newer' crops such as cotton, groundnut and maize.

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Annex

Average crop prices in the Atacora over 1994

crop	price per kg
Maize	63
Sorghum	72
Millet	74
Cassava	45
Cowpea	147
Groundnut	109
Cotton	130

Note: Prices are an average of monthly averages over 1994
Source: CARDER Atacora (1994)