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Nutrient cycling or soil mining? Agropastoralism in semi-arid West Africa

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NUTRIENT CYCLING OR SOIL MINING?

AGROPASTORALISM IN SEMI-ARID WEST AFRICA

Semi-arid production systems

R6603 / ZE0010

Final Technical Report

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EXECUTIVE SUMMARY

The aim of this research was to assess the sustainability of short-fallow farming in north-eastern Nigeria, as practiced in the village of Dagaceri. The research focused on nutrient cycling within the farming system, and the transfer of nutrients in livestock manure to fields.

There are two groups of farmers in this area, sedentary Manga and Hausa farmers, who live in villages, and also Fulani, whose traditional nomadic lifestyle has evolved to include a sedentary farming as well as pastoralism. While the two groups live separately, they are many interactions between them, including the exchange of manure, crop residues, and economic products.

Six farmers were studied through the course of one year, to monitor nutrient inputs and outputs from fields. Regular interviews were held with the farmers, to discuss their farming practices, the rationale for their actions, and the constraints they faced. At the same time, market prices of crops and livestock were monitored. This information was combined with labour monitoring data, provided by a second project, Soils, Cultivars and Livelihoods in north-eastern Nigeria (Mortimore and Adams, 1997).

A model of nutrient dynamics was developed, which considered nutrient flows between rangeland, fallow land and cropland managed by farmers, and the role of livestock in converting nutrients in crop residues and herbage into manure. The nutrient balance provided an indication of the success of the various farming strategies adopted by each of the six farmers. The sources of nutrient inputs and outputs was analyzed, and the dependence of each farmer on different inputs is discussed. Manure is an important input to the nutrient balance of farmers' landholdings, and farmers with better nutrient balances are those with greater ability to marshall nutrients from common access sources such as grazing land and refuse heaps to their own fields.

Constraints in the farming system included labour, poor return to fallow land, low nitrogen inputs, and problems with crop storage over longer periods. The fluctuations in the market prices, and high inflation in Nigeria, mean that the latter constraint has a severe effect on the potential value of a farmer's harvest.

It is recommended that increase nitrogen inputs by growing more legumes, which would also provide a more nutritious fodder for livestock, provide a high protein component to farmers' diet, and be a higher value crop for sale. Labour constraints concerning the recycling of crop residues could be relieved with an increase in the use of ox-carts. Provision of grain storage facilities would enable farmers to store grain until prices are higher, increasing the profitability of their farming, and allowing them to invest more money into their farming.

FOREWORD

This document records the results of a research project concerning nutrient dynamics in the short-fallow farming system of Dagaceri village, northern Nigeria, as carried out under the project R6603: Nutrient cycling or soil mining? Agropastoralism in semi-arid west Africa.

This project took place from January 1996 to September, 1997. The original proposal planned for 5 trips to be made to Nigeria. The first trip was to prepare the study, collect background information, and select farmers for detailed participation. The next three trips were to collect information concerning soils, vegetation, farming practices, markets etc., and the final trip was to allow a follow-up discussion and interview with the village community, and the specific farmers involved, to pursue questions raised by the research.

Work was progressing well, and according to plan, until the deportation of Michael Mortimore (project R6615: Soils, cultivars and livelihoods in north-eastern Nigeria) at the end of the third visit, in October, 1996. Although each project was separately funded, they were perceived as a joint project by Nigerians, as they involved complementary research agendas, and were based at the same Universities in the U.K. and in Nigeria, and worked in some of the same villages. This deportation effectively halted further trips to Nigeria. Attempts were made to collect outstanding information through Nigerian staff, but this was really only possible for existing data collection regimes. New work (such as dry season monitoring) could not be carried out, as a protocol had not been established with staff prior to the deportation.

As a result, the work planned for the last two visits, concerning post-harvest activities, crop sales, dry season monitoring of animal grazing practices, fodder harvest from fields, non-farming economic activities carried out in the dry season (cin rani), and rotation of fallow fields prior to the following season, could not be carried out. Furthermore, no interviews were possible once the harvest data had been collected and analyzed.

This report combines the results collected prior to the deportation, along with the information which it was possible to obtain by post, to provide a picture of nutrient dynamics in this farming system. Thanks are owed to Dr. J.A. Falola, Mallam Salisu Mohammed, Mallam Kabiru Ahmed, Mallam Bagana Bagana, Mallam Garba K/Naisa Adamu, the drivers Yakubu Mohammed and Adamu Gombe, and the farmers of Dagaceri, for doing their utmost to gather lacking information and send it to me.

1. *BACKGROUND*

There is increasing concern over the ability of African farmers to feed themselves while preserving the environment. As populations have expanded, it is feared that "fragile" environments can no longer support the demands to produce more and more. Words such as desertification and degradation have become commonplace. There is talk of marginal land and competition for resources. Most recently, there has been much written about soil mining, with the suggestion that eventually all the nutrient reserves in soils will be used up, and nothing will be left. At the same time, populations keep on expanding, so reducing agricultural land per capita, and increasing pressure on the land, winding up the spiral of degradation. Recently, a new source of data has been added to the debate: the nutrient balance.

Nutrient balance studies set the seen for the "nutrient gap" idea. Nutrient balances are negative, therefore farmers are mining their soils, and ultimately there will be no more nutrients, and the farmers will have to give up. These studies are useful in highlighting the need to ensure that nutrient inputs are balanced with nutrient removal, however they can suffer from limitations.

1. While they define a problem (based on approximations and generalizations), they do not provide any information on how to solve the problem (apart from the obvious one of apply more nutrients).
2. Nutrient balance studies take a very simplistic view of soil chemistry.
3. Even if the soil science is examined in more detail, a solution based on soil nutrients alone will not solve the problem, as the decline of soil fertility is not due to this alone.

Nutrient balance calculations must be broadened to identify nutrient cycles and models of flows. The benefit of developing nutrient cycles from nutrient balances is that flows can be quantified, and their relative importance established. Farmer-drawn diagrams of flows must be quantified to provide valuable development inputs.

The success or failure of a farming system is due to many issues, including social and economic factors, as well as agricultural technology, and soil fertility. Nutrient balances on their own say nothing about the surrounding factors.

The results of nutrient balance studies vary enormously depending on where the boundaries of the system are said to lie. Studies in the literature have considered nutrient balances at national, regional, village, farmholding, field and plot level (Stoorvogel and Smaling (1990), Van der Pol (1992), Harris (1998). The choice of the boundary affects the type of data available, and also the use of the results. National studies can take advantage of national import-export statistics, which may be more readilly available from standard sources (e.g. FAO data base). National studies can highlight the importance of the problem at a policy level, however they provide less information on how to resolve the problem.

When nutrient balance studies are carried out at the macro-scale, for example continental Africa, the actions of millions of people are compounded into one picture of irreversible, unstoppable environmental destruction. Yet mass actions are often more readily understood if we focus our studies on issues at the micro-scale, a level at which problems can be explained, constraints appreciated, processes understood, root causes identified, and interventions targeted to assist, and hopefully reverse, or at least retard, the environmental destruction.

Field or farmholding level data must be collected through fieldwork.Nutrient cycling studies carried out at the farm-scale offer direct measurement of nutrient input and outputs at the level where management decisions are actually made. When working at this scale, the constraints affecting nutrient management decisions such as knowledge, labour and capital, can be investigated. However such studies suffer from the inevitable criticism of being only a from the inevitable criticism of being only a "case study", thus not necessarily representative of the wider region, and may therefore be ignored by policy makers.

In order to fight the "nutrient gap", viable solutions must be developed. Viable solutions are those that are likely to be adopted by farmers, because they are acceptable in terms of economic factors, labour availability, cultural prejudices, markets, land tenure, local social organization and environmental effects. For this reason, it is important to study nutrient budgets not in isolation, but in the context of a farming system. Focusing the study at this level can identify the causes of the nutrient gap and the chain of actions which are leading to nutrient losses. Studies of nutrient cycling at the farm or village level can provide an understanding of the interaction of factors from which the nutrient gap arises. They can also provide an idea of what possibilities there may be to lead to an improvement in the nutrient budget of the farming system.

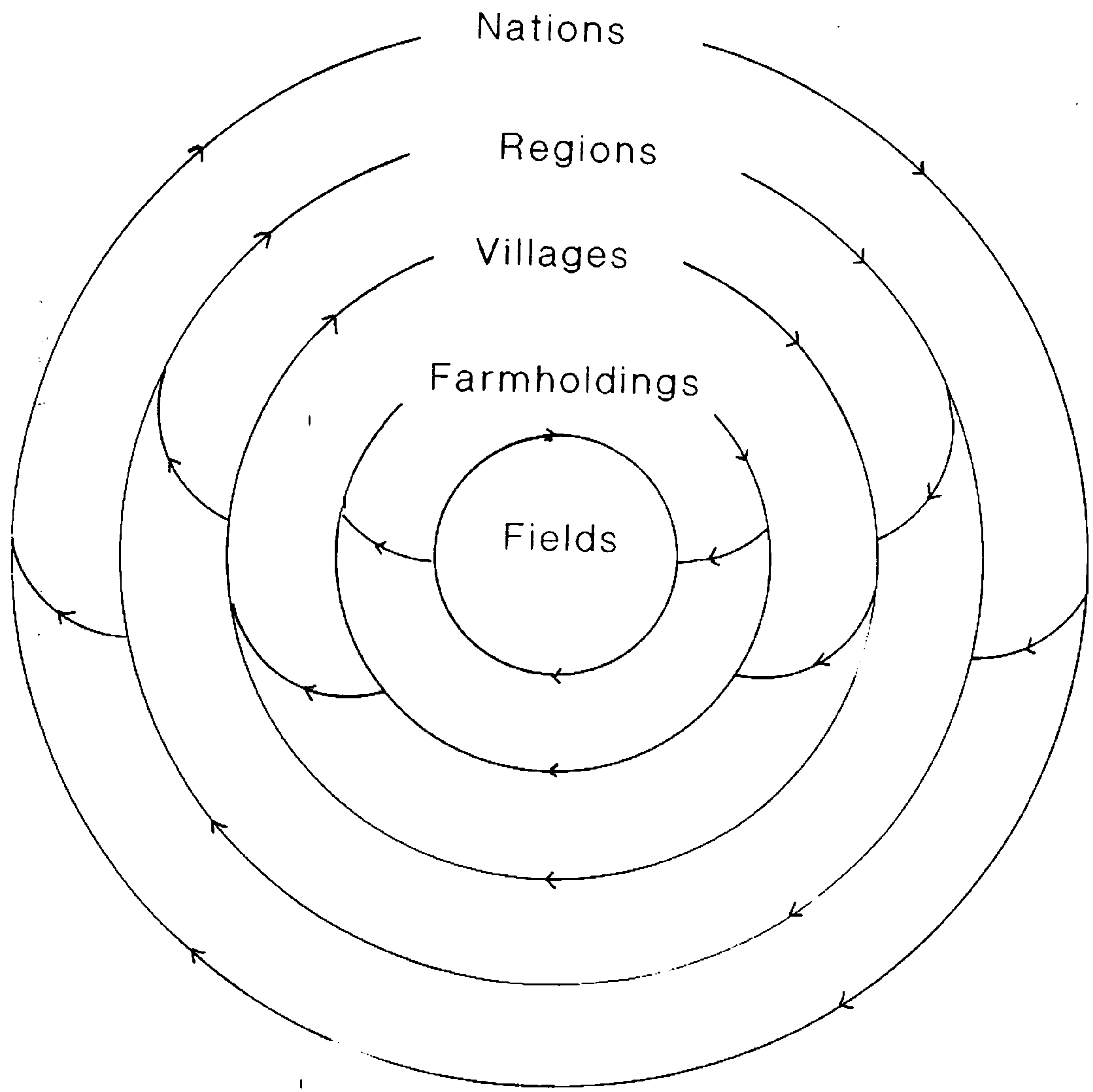
The nutrient cycle is a dynamic model which may be at equilibrium or disequilibrium. Each nutrient input or output is affected by many factors. A small adjustment at one point in the cycle can lead to a change further away, due to a series of knock-on effects through the system. The nutrient balance is only part of a larger cycle, and a series of concentric cycles starting with at the micro-scale with the field, and progressing through the farm, village, region, country, to the macro-scale (Figure 1). Each layer is affected by the environment, social/cultural practices, economy, labour, health, education, and conflict or stability.

A nutrient balance calculated at the country level does not provide information at the local level, and therefore that knowledge cannot help to bring about change. Change must occur at the level of the local nutrient balance. A local study is able to pick out what factors, at a wider level, affect the micro-scale.

In the Savanna/Sahel area of West Africa agriculture consists of cropping and livestock keeping. Sometimes each activity is practiced by separate groups of individuals, but often both activities are carried out by the same individual. The amount of integration of cropping and livestock raising activities varies. As cultivation intensity increases (Ruthenberg, 1971), the role of livestock in maintaining soil fertility through manure production becomes more important. With the integration of livestock and crop production the control of the important factors of fodder and manure comes under the control of the one individual, and he is now manipulating a more complex model of nutrient dynamics. This process is seen in the Kano close-settled zone, where a nutrient cycling study provided information on how this farming system functions and maintains soil fertility (Harris, 1998, Harris, 1996). This work also identified constraints within the system. The control of nutrient dynamics is a complicated manipulation of factors, and may pass through phases.

The law of limiting factors has relevance to nutrient dynamics within a farming system. The sustainability of the farming system may be limited by land, nutrients, labour (to move nutrients to where they are needed), markets, knowledge and experience. As a farmer overcomes one obstacle, another will become dominant. Similarly, as a farming system is intensified, first one and then another limiting factor must be overcome (Boserup, 1965). This study follows on from previous work carried out in the intensive, integrated farming system of the Kano close-settled zone (Bache and Harris, 1995, Agronomy and Cropping Systems EMC X0216). Its aim is to asses how the short-fallow farming system in north-eastern Nigeria can be directed to follow an intensification pathway that will lead to the development of a sustainable intensive farming system.

Figure 1: Nutrient cycles from micro to macro scale.



2. *PROJECT PURPOSE*

There is contrasting information concerning the sustainability of agriculture in semi-arid West Africa. Some research suggests a Malthusian pattern of land degradation resulting from population increase. but detailed research suggests that, in specific regions, population increase has resulted in the intensification of land use and improved soil fertility management. These individual cases show that the degradation scenario is not the inevitable outcome of population increase (Harris. 1996. Tiffen et al, 1993, Netting, 1993, Prudencio. 1993). As it is inevitable that populations will continue to increase in semi-arid West Africa, the study of these intensive areas has been useful in that they identify how farmers can intensify production in a more sustainable manner, and also the pathways by which this has been achieved (Harris. 1996). These "lessons" can then be applied to other areas.

Knowing that population increase will occur, and that extension of agriculture onto new land is limited by decreasing land availability, it is wise to act early to encourage farmers and herders to adopt practices which will increase output sustainably, rather than to wait until crisis point, to change a whole farming culture. Gradual adaptation to changing circumstances is better than sudden change.

The present work has focused on a short-fallow farming system in north-east Nigeria. In this area Fulani herders and Manga and Hausa farmers gain their livelihoods from raising crops and livestock. At present this area has a population density of $43/km^2$, yet populations in northern Nigeria are increasing, and this area represents an area in transition from extensive cropping and livestock raising to a more intensive and integrated system.

The aim of studying this system was to try to gain an understanding of nutrient dynamics in this short-fallow farming system, to identify constraints to the farming system, and what interventions might be made to encourage farmers to adopt farming practices which would conserve soil nutrients.

Field work focused on the identification and quantification of nutrient flows within the farmholdings of six local farmers, by a combination of monitoring and analysis of nutrient inputs and outputs, to identify the main sources and sinks of nutrients in the system, calculate a nutrient balance of farmers' landholdings. and develop a model of nutrient dynamics for the farming system.

Part of understanding farmers' soil fertility management practices involves an appreciation of the worth of crops, inputs. and the trade-offs between the use of equipment versus manual labour. This type of information is required if we are to understand whether it "pays" a farmer to carry out certain practices. It is believed that an indication of crop value at harvest, after storage, the value added in crop processing, and the cost of inputs such as labour. buying oxen and carts, and fertiliser. is important in any discussion of farmers' rationale for his soil management activities. and the relevance of any new recommendations. Labour inputs were determined by another project working in the same village (Soils. Cultivars and Livelihoods, R 6051. Adams and Mortimore). and this information was provided. Price monitoring at local markets was also carried out.

This report attempts to make recommendations concerning the present sustainability of this short-fallow farming system (based on the nutrient balance). farmers' management of soil fertility (based on nutrient cycles) and the way factors affect farmers' ability to manage soil fertility. Recommendations are made for adaptations which may enable farmers to intensify production while taking into consideration the sustainability of land use.

3. *RESEARCH ACTIVITIES*

3.1 Description of the farming system

The short-fallow farming system is located in north-eastern Nigeria. The area is populated by Manga and Hausa families living in villages (Mortimore, 1989). with encampments of sedentary Fulani surrounding the village. The traditional divisions between nomadic pastoralists and sedentary farmers have diminished, with both groups engaging in both crop and livestock production. However the Fulani priority is still cattle rearing, and the Manga and Hausa priority is crop production. The main crops are millet (Pennisetum typhoides), sorghum (Sorghum bicolor) and cowpea (Vigna unguiculata (L) Walp.).

Dagaceri is situated in a Sahelian environment. Rainfall averaged 360 mm per annum between 1992 and 1995. A landscape of rolling dunes is punctuated by small dispersed villages. Vegetation consists of sparse trees (Adansonia digitata, Acacia spp., Balanites aegyptiaca) and shrubs such as Boscia senegalensis, Gueira senegalensis, Leptadenia pyrotechnica and Hyphaene thebaica (Mohammed, 1996).

Figure 2 shows land use in the village area based on air photographs (1981). The village is surrounded by fields, some of which may be cultivated annually, with others under rotation, during which they may be left to fallow for short periods. Further from the village are areas of rangeland. Cattle tracks, roads and paths cross the area, allowing vehicles, carts and donkeys to travel across the farmland area, and livestock to access watering points, or rangeland further away.

The soils in the area are classified as brown and reddish brown soils of the arid and semi-arid regions (d'Hoore, 1964, as quoted in Mortimore, 1968), or tropical ferruginous soils (Jones and Wild, 1975) which are considered equivalent to Ferric Luvisols (Landon, 1991, pg. 239). The soils are sandy (85%), of pH 6.0-7.0, with a bulk density of 1.4 g/cm^3, and organic carbon content of less than 0.1%. Slope angles are usually 1-2 degrees (Ahmed, 1997).

Soils are classified locally as keza-keza (white), found at the top of dunes, katikime (red), found on dune slopes, having low organic matter and water holding capacity) and tulo-tulo (black), found in depressions, and having greater water holding capacity.

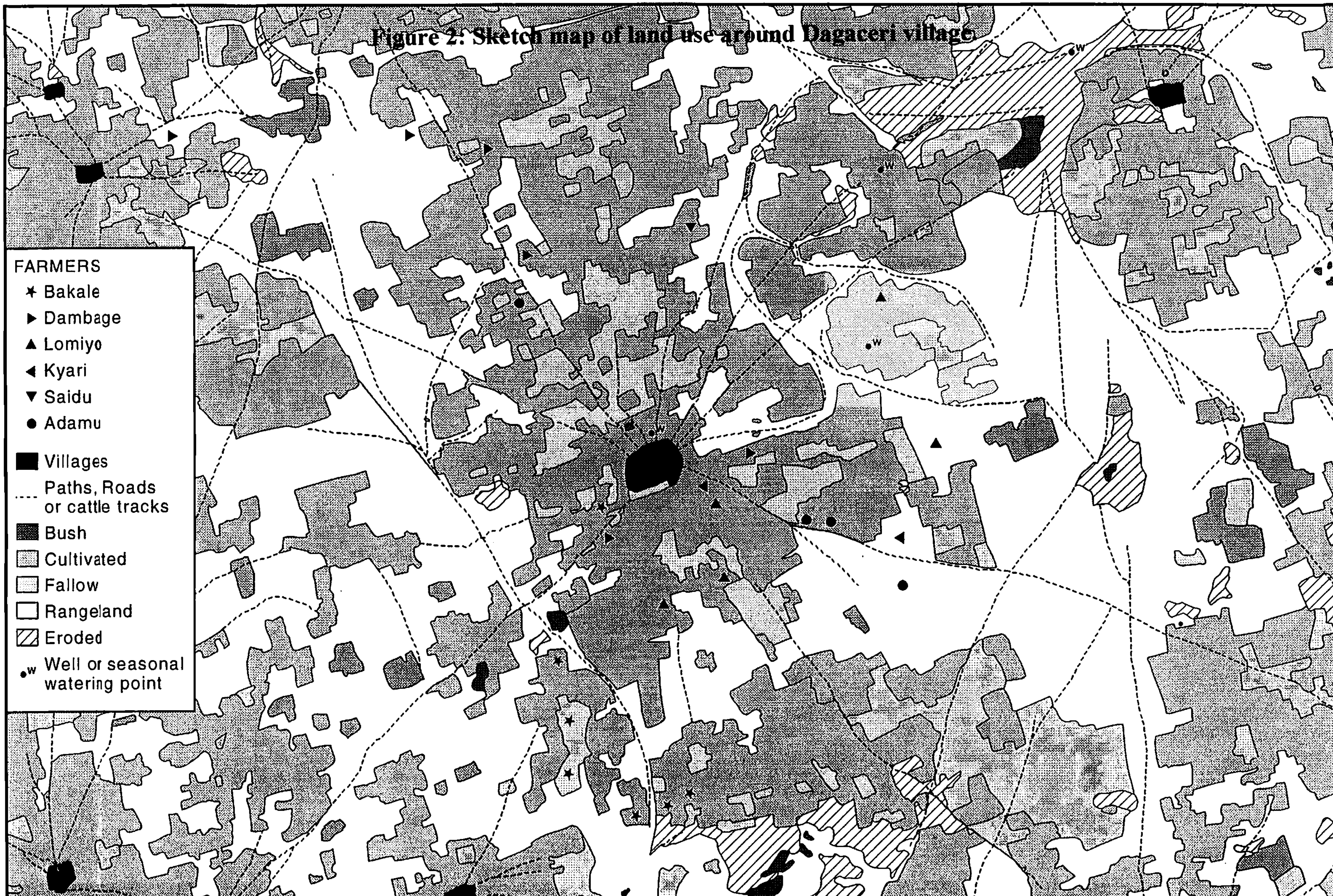
At the village, compound sweepings are left on refuse heaps at the edge of the village. These heaps contain organic material such as stalks, kitchen waste, small ruminant manure. and also cooking ash. During the dry season farmers may take any of the refuse to their fields, either by headload, donkey or ox-cart. In addition, some farmers may take manure from within their compounds, which was produced by their personal livestock.

The rainy season begins in June or July. Field preparation begins in April or May as farmers clear shrubs (Boscia senegalensis, Gueira senegalensis Hyphaene thebaica), and occasionally burn remaining grasses, if they have not been consumed by livestock herds. Some farmers fertilize fields with manure or village refuse.

Farmers may dry-plant in anticipation of the rains, however, at the first rains planting begins in earnest. As soon as seeds have germinated, a first weeding is accomplished using the ashasha (a locally made hoe). Only fields where germination has been successful are weeded. Other areas may be abandoned, or planted a second time. Due to labour shortages many fields or sections of fields are never planted, or abandoned if the crops do not germinate well. Therefore within a field there may be planted and fallow areas. In 1996, early rains waned, and a long dry period elapsed before the rains began in earnest in late July. Farmers watched their crops wilt, and some die. Some fields were abandoned. Others were re-planted after the strong rains in late July. Planting continued well into the rainy season - either gap-filling, or planting beans between rows of cereal crops.

Harvest begins with the millet in September. followed by beans. Sorghum is harvested in late October or November. The harvesting period is a very busy one, as the areas that are planted are large, and farmers must take the grain to

Figure 2: Sketch map of land use around Dagaceri village



Sketch map derived from air photo sources, 1980 the storage granaries after drying, and stack cereal stalks if they do not want them to be consumed by grazing livestock.

As the millet is harvested, some farmers begin to plant guna melon (Citrullus lanatus). This crop grows on residual soil moisture, and is harvested from February until April. It is very susceptible to attack by pests, and so the crop is only successful in some years.

Farmers and herders share the fodder production of the village area. The village livestock (small ruminants) are taken to graze every day by one of the village residents. Cattle (whether owned by Fulani or farmers) are usually herded by Fulani. The village is surrounded by fields, with rangeland further away (Figure 2). Grazing reserves also exist for the livestock, but are located several kilometres from the village. During the rainy season Fulani are expected to keep their herds from cultivated fields, although grazing fallow fields is permitted, providing the herder can gain access to them without his livestock damaging crops in neighbouring fields. At this time of year movement of the herds from corrals to wells or watering holes and then to pasture must be along cattle tracks. Cattle tracks are well travelled, and allow very little grass and herbage. During the dry season, farmers are willing to allow cattle access to their fields, as this may result in cattle manure being left on their fields. However in years when farmers grow a dry season crop of guna melon fields bearing guna are not to be grazed.

The village contains a grain bank, run by a committee composed of the villagers. Farmers may sell their grain to the grain bank, or at public markets. The nearest markets are at Birniwa and Kumsa, and operate on a weekly basis. There is also a larger market, further away, at Nguru.

3.2 Methodology

This research aimed to study nutrient dynamics and land management in the socio-economic context of small-holder farmers. Data collection focussed primarily on farming practices and nutrient movements within the farming system, and market values of crops and livestock. Interviews with farmers discussed the interactions and interrelationships affecting resource use by farmers, and particularly interactions between livestock and the fields. The market study aimed to value nutrient inputs and outputs and intensification technologies, and whether the costs of increased labour, inorganic fertiliser and plough-hire may be offset through the sale of surplus crops, livestock etc.

While most research was carried out the farm level, and the results are presented as farm-level balances, some information was collected field by field (inputs and harvest), and other information on a more regional scale (nitrogen fixation by beans, woodfuel harvest, Harmattan dust). The results are used to identify the constraints to increasing production, and the options for smallholder farmers to develop a sustainable intensive production system which would meet their needs, and allow them to intensify agricultural production while meeting their needs and priorities.

3.3 Preliminary Farmer Selection

Thirteen farmers in the village have been involved in a study of agropastoral adaptation to environmental change, with particular reference to soils, cultivars and livelihoods, since 1992 (Mortimore and Adams, 1997). Their research work has included interviews on specific topics and issues such as land use change, cultivars, environmental change, village history and demographic change, soil properties, and also daily monitoring of agricultural labour in each rainy season since 1993.

Early in 1996 the 13 farmers were interviewed about their farmholdings and soil fertility management practices (Table 1). The results show that each farmer owns several fields (with the exception of the Fulani, who has 1 large, consolidated landholding), and cultivates slightly more than half of his landholding. Some cultivate all of their land. Most try to manure some of their fields, but many must do this by carrying headloads of manure to the fields, and therefore only the closer fields receive this input. Without some form of transport, manuring fields which are far

Table 1: Summary of results of interviews with 13 farmers in Dagaceri village, 1996.

Farmer	family labour *	total # fields	approx. total land (ha)	# cultivated fields	# fallow fields	plough ownership	cart ownership	hiring of plough or cart	manuring	inorganic fertilizer	fallow rotation
Mambadu	2.7	5	7.1	approx. 5	0	no	no	can't afford it	no	no	no
Dambage	5.2	3	5.7	3	0	no	no	hires both	very year, each fie	no	no
Ba-Kadai	1.9	6	11.6	5	1	no	no	hires for fields 2 & 6	only fields 4 & 5	no	no
Tela Nakuri	3	6	4.4	approx. 4.5	1.5	no	no	no	a	no	no
Bagana Lomiyo	2.2	5	9	3	2	sold	broken	no	a	no	no
Mallum	3.4	6	11.4	5	1	no ****	no	2 eastern fields ploughed every year	a	not recentl	no
Bakale	3.3	5**	15.6	3	2	yes	acquired 1996	offers ploughing for others	yes	no	no
Mai	2.2	4	5.6	3	1	no	no	sometimes 1	a	no	no
S. Mohammed	2.2	3 or 4	7.1	3	approx 0	no	no	first time, 1 field	no	2 years ag	no
Sule Adamu	2.7	7	19	5	2	no	no	hires plough for some	yes *****	no	yes ******
Sani Dogo	2.2	3	6.3	2	1	no	no	ploughs field with heavier soil	no	no	no
M. Kyari	2.3	3	20.5	3***	0	no	no	hires plough	no	no	yes
Saidu	7	1	14.6	partly cult'd and fallowed		no	no	hires plough sometimes	no	no	yes

* Labour wieghting:
adult male 1 | adult female, young male, aged male 0.7
child 0.3 | aged female, young female 0.5

** owns other fields which are on loan to other farmers
*** large fields, parts of which are left uncultivated
**** brother of richest man in the village, who owns a plough

***** produced from personal livestock
****** for 40 years
a to closest fields, usually by headload

Labour inputs were determined by Mortimore and Adams. Field areas were determined by both projects.

Family labour was monitored by Adams and Mortimore. Field areas were determined jointly by both projects.

from the compound is difficult. Inorganic fertiliser is not widely used. Ploughs and carts are owned by some farmers. Those who do not own them may hire someone to plough a field at the onset of the rainy season.

The extremes are represented by Mallam Mambadu, who does not do anything to improve soil fertility, and Mallam Bakale, who has a surplus of land, owns bulls, a plough and a cart, and manures his lands heavily. Alhaji Dambage hires both a plough and a cart to plough and manure his fields. He also works as a butcher. Sule Adamu manured many of his fields, using his donkey to transport it. The Fulani herder, Saidu, moves the position of his corral through the seasons so that each year a different area of land receives lots of manure, and is then cultivated. Farmers with larger landholdings can practice rotational fallowing. M. Kyari does not manure his land but can practice rotation and leave fields fallow for considerable periods. Sule Adamu, Bakale and Saidu also do this.

The detailed nature of the monitoring work limited the number of farmers which could be included in such a small-scale (in terms of manpower) study. For this reason only six farmers were selected for the research. By interviewing thirteen farmers (more than half of the farmers in the village) it was hoped to provide a picture of the range of farming households and soil fertility management strategies operating in the village, and put the "case study" of six farmers into a more general context.

Based on the results of these interviews, six farmers were asked if they would participate in the research, and consent to have their farming practices monitored during the 1996 agricultural season.

The six farmers were not selected to be typical, but because they practiced a variety of contrasting soil fertility management practices. The six selected were as follows:

1. Saidu: a Fulani herder and farmer
2. Bakale: a large landowner who was also owned a plough and cart
3. Lomiyo: a small landowner who recently lost his cart (broken)
4. Dambage: a small landowner who practiced intensive manuring.
5. Kyari: a large landowner, who practiced fallow rotation
6. Adamu: a large landowner practicing short-fallow rotation, and intensive manuring.

In this way, 6 farmers with contrasting soil fertility management practices were studied. Nutrient inputs and outputs on each of their farmholdings were assessed during the following agricultural season.

3.4 Measurement of inputs

3.4.1 Livestock Manure

Livestock manure on fields comes from three sources: that originating from households and the village and brought to the fields by farmers, from cattle corralled on land, and from grazing herds of ruminants.

Manure brought to fields from households and the village

Farmers who owned livestock which they kept in their compounds were able to collect the manure and take it to their fields - by donkey-load or cart-load if they owned a donkey or oxen and a cart. Others either borrowed or hired transport, or headloaded it. Those without sufficient quantities of manure in their compound could avail themselves of communal refuse heaps on the outskirts of the village. This material has less manure and more ash and straw than composted animal manure. Farmers reported the amount of manure taken to each field. Sixteen samples of manure were taken and analysed (Table 5), and manure quantity multiplied by nutrient concentration provided nitrogen, phosphorus and potassium inputs in manure.

Manure from corralled herds

Of the six farmers studied, only Saidu was in a position to fertilise his land in this way. He corralled his herd of cattle in a different area of his farmland every year so that the area could be planted to grain in the following rainy season. To measure the manure input, 10 quadrats ($1 m^2$) were placed on the soil surface, and all manure collected and weighed. The manure within each quadrat ranged from 73 - 448 g/m^2, with an average of 252.1 g/m^2 (standard deviation 118). Thus, on average, the manure in the quadrats was equal to 2.5 t/ha on the cultivated land.

Schlecht et al. (1995) measured faecal organic matter (OM) from cattle at 1.8-2.4 kg OM/day, of which 43% was voided at night. Saidu's herd contained 29 animals at the end of the 1995 dry season. Thus 29 animals producing 2.16 kg OM/day (average of Schlect et al.'s values) for 365 days would produce 22864 kg of manure per year. If 43 % of the manure is voided on farmland, this would provide 9831 kg/yr to fertilize the land. Therefore average manure on landholding (= 9831 / 14.1) would be 697 kg/ha. However as this is concentrated onto the cropped land (6.1 ha in 1996), the level of manure application to the cropped fields would be 1612 kg/ha. This is lower than the 2.5 t/ha measured.

The difference between the results of this study and that of Schlecht et al. may be due to Saidu's herd having been recently reduced in numbers as fodder supplies waned, his livestock spending more time on the farmland, or because his livestock were better fed than those in the Schlecht study and so produced more manure. Saidu himself said that he preferred to have a herd of 50 animals, and if this were the case, they would produced sufficient manure to supply 2.8t/ha to the cropped land.

Manure from grazing herds

There were approximately 5 herds of 40 cattle operating in the village area (1800 ha), producing 5 x 40 animals x 2.16 kg OM/day x 365 days of the year = 157,680 kg manure per year. Assuming 57 % of this manure was distributed during the day while the animals were grazing farmers' fields or rangelands, then 89,878 kg of manure are spread over an area of 1800 ha, which is equivalent to 50 kg/ha/yr.

The village herder estimated that the village owned 1,000 small ruminants, of which 700 were female, 300 male, and 600 more than one year old. During the dry season these animals were taken to farmland for grazing, but during the rainy season went as far as the grazing reserve near Dalari if necessary. Although animals grazed the land, they were also fed within the compounds. Fernandez-Rivera et al.(1995) state that animals fed ad libitum produce the following amounts of manure: cattle 2.38 kg OM/day, sheep 0.35 kg OM/day, goats 0.20 kg OM/day. The average for sheep and goats is 0.29 kg OM/day. It was assumed that adult small ruminants who receive fodder in the compound as well as graze daily are amply fed, and so produce this amount of manure, and small ruminants younger than 1 year produce half this amount, then the village herd will produce ((600 x 0.29) + (400 x .145)) x 365 = 84680 kg OM/year. If 43% is voided at night when the animals are tethered in the compounds, 57% is divided over fields and rangeland, an area of 1800 ha. Thus 48268 kg OM is spread over 1800 ha, providing 26.8 kg OM/ha.

It was assumed that this manure was distributed equally between rangeland and farmland. Therefore total manure contributed to fields and rangeland from grazing animals (cattle and small ruminants) is 26.8 + 50 = 76.8 kg/ha/yr.

3.4.2 *Inorganic fertiliser*

Those farmers who used fertiliser were asked how many bags of fertiliser were used, and what type it was. From the fertiliser type, nitrogen, phosphorus and potassium content were known. Only three bags of fertiliser were used by the farmers monitored in this study. Lomiyo and Dambage each used one bag of NPK, and Kyari used 1 bag of SSP.

3.4.3 *Harmattan dust deposition*

Harmattan dust deposition was measured using a wet dust trap, following the examples of McTainsh (1982), Bayero University Meteorological Station (Mortimore, pers. comm.), and experience in the Kano close-settled zone (Harris, 1995). Two traps were set up at two separate locations in the fields around Dagaceri. The traps were sampled every 2 weeks, and the water and dust taken to laboratories at Bayero University for evaporation and weighing. Dust deposition was calculated by summing dust in the traps, and correcting for secondary deposition (McTainsh, 1982). Dust deposition was calculated to be 740 kg/ha. Nutrient content of the dust was determined by McTainsh (1982) to be 0% nitrogen, 0.09% phosphorus and 2.03% potassium.

3.4.4 *Symbiotic biological nitrogen fixation*

Following a procedure developed in previous years (Harris, 1995, Hauser, 1992), nitrogen fixation in farmers' fields was estimated using the nitrogen difference method (Giller and Wilson, 1991). Local bean varieties were grown alongside a companion crop of sorghum. The nitrogen uptake by beans was compared with the nitrogen uptake by the companion crop, and the difference in nitrogen uptake attributed to nitrogen fixation. Initially two experimental plots were prepared, and planted to millet, sorghum, and beans (three types: early, medium and late maturing). The plots had not received any fertilisation in the previous year, neither were they fertilised during the trial. Due to poor rains in the early part of the rainy season, and damage by grazing animals, the crop on one of the plots was not successful, and so this plot was abandoned. Therefore the results presented here are those from a single trial. The results indicated that nitrogen fixation might provide 1.76 g nitrogen / bean stand.

A survey of the cropping patterns in 10 by 10 m plots in 15 fields ascertained that beans are planted at an average density of 1407 stands/ha, which means that 2.5 kg/ha of nitrogen are contributed to the farming system through biological nitrogen fixation by beans. (Taking into account the estimation technique, this figure could be expected to vary from 0-5 kg/ha. This will be discussed in the sensitivity analysis, section 4.2).

3.4.5 *Fallow land*

The original work plan had involved some sort of measurement of vegetation growth on fallow land, combined with vegetation sampling and analysis, to estimate biomass regeneration during fallow periods, and nutrient gain to fallow fields. Due to the unfortunate circumstances of October 1996, it was not possible to return to Dagaceri during the dry season of 1996-1997, when this work was to be carried out. The data concerning herb and shrub growth on fallow and rangeland are based on preliminary investigations which were carried out in July and September, 1996, with a view to elaboration in the dry season.

Fallowing land is assumed to allow it to regain soil fertility through nutrient accumulation in biomass, nitrogen fixation, parent material decomposition, atmospheric deposition etc. In the absence of field data from Dagaceri itself, the project resorted to the literature. A thorough review of this by Stoorvogel and Smaling (1992) lead them to conclude that fallow in general accumulates 2 kg N, 2 kg P_2O_5, and 1 kg K_2O/ha/yr. (Stoorvogel and Smaling, 1990), and these figures have been used in this study. In fact, fallow land in this area is still used to provide fuelwood, tree products and fodder. These nutrient removals were considered separately.

3.5. Measurement of outputs

3.5.1 *Millet and Sorghum Harvest*

All of farmers' harvested cereal grain and stalks were weighed. Farmers were asked to provide a sample of 10 heads of each crop, the ten heads being selected in proportion to the different varieties of millet and sorghum grown (see Mortimore and Adams, 1997). The 10 heads provided by each farmer were combined, threshed, and then samples (one sample from each farmer) of plant parts were taken and analyzed for nutrient content. Six samples of each crop component (millet grain, millet chaff, sorghum stalks, bean pods etc.) were analyzed for nitrogen, phosphorus and potassium content in duplicate. Threshing measurements were used to convert harvested grain into its component parts, and nutrient removal was calculated.

3.5.2 Cowpea Harvest

Farmers intercrop cereals with cowpea. They harvest only the beans, leaving the vines on the fields. These decompose rapidly, although a small amount may be left to be consumed by grazing livestock. Cowpea yields were measured in a cowpea trial carried out in 1993/4, which showed that cowpeas yielded 50 kg/ha (Mortimore and Mohammed, unpublished data).

3.5.3 Pasture grasses

All fields that are not cultivated grow a crop of weeds and grasses. In order to estimate the amount of herbage produced, and the amount taken off by grazing animals, two enclosures were built on rangeland areas, to protect a small area from grazing, and so provide an estimate of total biomass production on rangeland during the rainy season. More sites could not be enclosed, as it would reduce rangeland available to livestock herders, and it was felt that herders would become antagonistic if we were interfering with their pasture, even if the area was, in reality a small fraction of the pasture available to them. Each enclosure was approximated 20 m by 20 m, and then surrounded by some thorny bushes to prevent animals from breaking down the rope that marked out the enclosed area. As it was, herders and livestock invaded one of the enclosed areas, leaving only one undisturbed enclosure for measurement. It was intended to repeat this exercise during the following dry season, however due to the deportation, this was not possible.

It was known that some fallow fields are surrounded by cropped fields during the course of the rainy season, so that it is impossible for gazing livestock to gain access to the weeds growing on them. Thus these are effectively "enclosed" areas as well. At the end of the rainy season, quadrat studies were used to measure the amount of biomass growing on enclosed and grazed rangeland, and on enclosed and grazed fallow land.

Four sites on rangeland and 12 sites on farmers' fields were visited, and at each measurements were taken in triplicate. Twenty quadrats were measured within an enclosure of rangeland. The results are shown in Table 2.

These results show that there is considerable variation in the naturally occurring vegetation within the enclosure, within which clumps of taller grasses, and areas of shorter grasses were observed, with areas that were thickly or sparsely populated. This is seen in the range of yields from adjacent quadrats.

The range of species present at fallow sites varied. In fallow fields, the most common species were Spermacoce stachydea (Dc) (found at 75% of fallow sites, but only 25% of rangeland sites), Andropogon gayanus (Knuth). (found at 50% of fallow sites), Corchorus olitorius (Linn) and Cenchrus biflorus (Roxb.). In the cattle tracks, common species were Desmodium lasiacarpum (Dc) and Schoenfeldia gracilis.

Assuming no significant difference between the various categories of sampling site, the average is 1259 kg/ha of biomass produced.

Several quadrats were taken on grazed and ungrazed fallow fields. The results are shown in Table 3.

The results of quadrat measurements at rangeland and on the fallow fields depicted in Table 3 show that the amount of vegetation remaining on land that has been grazed may vary considerably, possibly due to incomplete grazing, as well as variation in the amount of vegetation originally present prior to grazing.

Thus some grazed areas still have a lot of fodder remaining, and others do not. The amount of fodder removed will depend on the time spent grazing the field. It is not possible to estimate the amount of biomass removed by grazing animals from these measurements, but it can be assumed that whatever is not grazed will be cleared and burned.

Table 2: Herb and grass biomass on rangeland and fallow fields g/m2.

	Site	rep 1	rep 2	rep 3	avg.	stdev	section avg.	stdev	all data avg.	stdev
Rangeland	A	59	24	51	45	18	114	65	126	67
	B	55	73	96	75	21				
	C	130	115	207	151	49				
	D	208	181	170	186	20				
Fallow	E	88	111	130	110	21	136	65		
	F	193	70	68	110	72				
	G	154	118	148	140	19				
	H	92	89	107	96	10				
	I	93	148	261	167	86				
	J	275	111	146	177	86				
	K	114	111	224	150	64				
	L	157	120	179	152	30				
	M	66	97	75	79	16				
	N	109	277	93	160	102				
	O	107	320	173	200	109				
	P	94	114	66	91	24				
Enclosure	Q	102	45	78	101	50	115	70		
		152	39	180	231	123				
		65	153	76	236	69				
		224	51	221	62	37				

Table 3: Herb and grass biomass on grazed and un-grazed fields.

description	no. quadrats	avg. yield (kg/ha)	stdev	range
grazed	5	1890	270	1550-2370
grazed	10	550	350	100-1100
not grazed	10	1470	260	190-2000

3.5.4 Shrub growth

The number of shrubs and their species within 8 quadrats of 2500 m^2 were noted. Five plants were selected from within each quadrat for cutting using a stratified random sampling technique. When dry, the wood and leaves were weighed. The results are given in Table 4.

Table 4: Shrub growth in the area of Dagaceri village.

Location	n	avg. wt of leaves/shrub (g)	avg. wt of wood /shrub (g)	total leaves in quadrat (kg)	total wood in quadrat (kg)	main species
field	150 (144)	287.8	1179	43	177	Guiera
farmland	118 (116)	398	1717	47	203	Boscia
cattle track	34 (30)	73.6	3022	2.5	10	Boscia
rangeland	103 (103)	436.2	1810.4	50	186	Boscia
rangeland	39 (39)	290	2012.4	113	78	Boscia
rangeland	91 (64)	272.6	1026.4	10	105	Gueira
rangeland (dune crest)	46 (38)	208.2	2275.6	10	105	Gueira and Boscia
rangeland	87 (83)	75.2	1525	7	13	Boscia

In general, only Gueira senegalensis and Boscia senegalensis were weighed, despite the fact that a small number of individuals of other species were present. The numbers in brackets indicate the number of Gueira and Boscia only. The shrub vegetation is composed mostly of Gueira and Boscia (91%).

Averaging the results across all plots, there are 77 Gueira and Boscia plants per quadrat, which comes to 308.5 shrubs/ha. (range 120-576). This biomass was composed of leaves (148.8 kg/ha, range 10-452) and wood (432.5 kg/ha, range 40-812).

These results give a measure of biomass production, but not of offtake. Benjaminson (1993) summarised research results concerning average fuelwood requirements for families, and concluded that fuelwood offtake was on average 1.29 kg/capita/day, which is equivalent to 471 kg/capita/yr.

Mortimore and Adams have calculated the population density of Dagaceri to be 43/km^2 (Mortimore and Adams, 1997, Annex 2, page 2). 1 km^2 =100 ha, therefore the population density is 0.43/ha. Therefore the fuelwood offtake is 0.43 x 471 = 202.5 kg/ha/yr.

Air photo interpretation has shown that there are on average 2 trees/ha. At this low density, their input to the nutrient cycle was considered to be negligible.

3.5.5 Leaching

Soil moisture as considered in detail by the project counterpart in Nigeria, Mallam Kabiru Ahmed. Full results of his work can be seen in Ahmed, 1997. The work is summarised here.

The rainy season in Dagaceri is largely limited to the period between July and September. There are on average 39 rain days recorded during this period, with intervening rain-free periods of 3-5 days in July and September, and 2-3 days in August. The largest rainfall occurrences are from 2-4 cm of rainfall. Infiltration rates are high, and therefore surface runoff potential is low. A runoff plot established during the 1996 rainy season collected nothing. Ahmed concluded that soil water loss is mainly due to evaporation. Further measurements indicated that the soils never reached field capacity, and thus infiltration does not lead to deep drainage and groundwater recharge and thus leaching of nutrients does not occur.

3.6 Chemical analysis of inputs and outputs

Samples of inputs and outputs were taken. All samples were air dried, and then bagged and shipped to England for chemical analysis to determine the concentration of nitrogen, phosphorus and potassium in them. Total nitrogen was determined by semi-micro Kjeldahl followed by Markham distillation. Phosphorus and potassium were determined by ashing samples and taking up the remains in HCl. Phopshorus was determined by flow-injection analysis using the vanado-molybdate "blue" method, and potassium by flame photometry.

Given the variability of manure nutrient concentration, the grand average was used in the calculations of the nutrient balance. Literature values were used to calculate nutrient removal in grasses and harvested shrub wood.

Table 5: Chemical analysis of manure.

	n	N		P		K	
		avg.	sd	avg.	sd	avg.	sd
small ruminant manure	5	1.48	.72	.16	.06	1.38	.56
manure & grass	2	.67	.47	.07	.01	.63	.24
manure and ash	6	2.1	2.67	.19	.07	2.41	2.64
cattle manure	1	.78		.11		.32	
sheep manure	1	1.42		.19		.49	
donkey manure	1	.98		.15		.75	
grand average	16	1.24	.71	.15	.06	1.00	1.75

Table 6: Chemical analysis of crops.

		N		P		K	
		avg.	sd	avg.	sd	avg.	sd
millet	grain	1.80	.29	.30	.04	0.44	.04
	chaff	1.09	.30	.17	.05	0.73	.34
	sticks	1.19	.11	.20	.05	1.49	.27
	stalks	0.87	.34	.08	.02	2.29	.49
sorghum	grain	1.79	.18	.30	.05	0.47	.08
	chaff	0.56	.08	.10	.02	0.74	.09
	sticks	0.76	.15	.12	.03	1.06	.19
	stalks	0.57	.21	.08	.03	1.75	.51
beans	grain	3.64	.23	.30	.03	1.36	.09
	pods	1.45	.19	.10	.02	2.06	.26
	straw	1.67	.22	.13	.03	1.88	.44

3.7 Market values of farm products

Dagaceri has two markets nearby, and a further regional market, at Nguru. Each operates once a week. The two closest markets (Kumsa and Birniwa) were monitored for grain and livestock prices. By combining data collected by staff of two research projects, data concerning prices were obtained (Figures 3-6). Livestock prices were initially based on prize animals, but later based on the price of an animal of medium size in average condition. However, the quality of the animals will vary throughout the year.

3.8 Farm labour

The farming tasks of 12 farmers in Dagaceri village were monitored by R6015: Soils, cultivars and livelihoods in north-east Nigeria. Preliminary results and analysis of this data is contained in Mortimore and Adams, 1987, and detailed discussion of the role of labour in farming systems in north-east Nigeria will be found in their work in preparation: Mortimore and Adams, Working the Sahel: labour management in four villages in the Nigerian Sahel.

For the purposes of this study, data concerning labour input to farming and livestock keeping by the farmers has been provided by Mortimore and Adams. Unfortunately, one of the farmers involved in this study (Bakale) was not included in the labour monitoring work.

Labour monitoring was carried out from June 1 to November 14, 1996. This period does not encompass all of the farming season's activities, as it excludes some field clearance and preparation activities and dry planting. Manuring is an activity that is carried out throughout the dry season, and well into the early rainy season. thus some manuring may be recorded, but not all. Harvesting of sorghum continued until after this period, and any work concerning guna, a dry-season crop, was not recorded. However the monitoring does allow us to compare labour inputs between the five farmers who were monitored over the same period. The information recorded concerns farming tasks, and excludes household tasks, marketing activities, and other non-farming activities.

Farm labour prices during the 1996 year were N140 for the period 7:00 am to 2:00 pm during the rainy season. (This represented an increase of N40 from the previous rainy season). During the preceding dry season. farmers were paying N60 for labourers to help them work on guna from 7:00 am to midday.

The hire of a cart cost approximately N30 per journey, N50 if the load was to be taken to a field far away. Ploughing cost N1,200 per year. Obviously these last prices are approximate. as they will vary according to distance, the size of the load, and, in the case of ploughing, the size and condition of the fields.

4. *OUTPUTS*

4.1 Description of the six farmers studied.

4.1.1 Saidu

Saidu is a Fulani sedentary pastoralist. Saidu's landholding is consolidated in one unit. This is divided into a cropped area and fallow area. Thus he cultivates one big field. The remainder of his land is fallow. Cattle are tethered in the fallow area during the cropping season. That area becomes the cropping area in the following rainy season.

Saidu claimed that if he had plenty of cattle, he would stop farming and would buy crops to feed himself. At present he says he has 29 cattle, with the herd mostly composed of females. Farming provides the food, and the cattle provide milk. He usually produces enough food to feed his family, except in poor years. He does most of the farming himself, with a little bit of labour hiring and a little help from his wives.

Saidu has more land than he needs for farming, but it is required for his cattle. Fulanis share the rangeland, even in times of fodder scarcity, and walk to boreholes across each others' land. However stalks are privately owned. Saidu saves his cereal stalks for feeding his cattle. In 1996 he had collected two large stooks which he said would feed his herd for 3 months, from April until the rains, when his rangeland would start producing animal fodder. In 1996 all the stalks were from his farm, although he had paid people to gather it into the stooks. Some years he buys stalks from farmers.

4.1.2 Bakale

Bakale was managing 5 fields at the beginning of the 1996 farming season: 2 large cultivated fields, 1 smaller field, and 2 fallow fields. He owns other land which he lends to other farmers. He doesn't sell his extra land because he wants to give it to his children (4). Fields loaned out to other farmers were not considered in this study, as these tend to be long-term loans, where the year-to-year management of the fields is under the control of a different farmer.

Table 7: Bakale's landholding in 1996.

Field no.	Local name	Soil type	History
603	Yamma da Karkudiya	keza-keza and tulo-tulo	27 years of continuous cultivation
S409/643	Gonan jiji	tulo-tulo and black keza-keza	30 years continuous cultivation
609	bakin burtali hanyan kiria	east: tulo-tulo west: katikime	fallowed from 1979, cultivated in 1995
S302/610		*	fallow for 12 years
228	yamma da gari/yamma kusa	keza-keza	fallowed for 5 years prior to 1995
312			on loan
406	yamma da wargale		

** this field was not grazed because it was surrounded by fields of guna.*

Bakale has been farming for approximately 30 years. He owns a pair of bulls, but hires a plough (at cost of N600 for 1995, N 1,200 in 1996), to plough some of his land. In 1996 he received a loan to purchase a cart, and now he has begun to take manure to his fields. He collects manure from communal refuse heaps or from threshing floors. Cattle sometimes graze on his fields, but do not leave much manure. He does not use inorganic fertiliser.

4.1.3 *Bagana Lomiyo*

Bagana Lomiyo owns five farms, with a total area of 9.0 ha. He is the oldest of the 6 farmers studied. He used to use a cart, but it is now broken, and no longer operable. Thus the only manured farm is kudu kusa (433), because it is close to the village. Manure is taken by headload. When the cart was working he used drive himself to his fields in it, carrying drinking water, but not to transport manure. He also used to own a plough, but it was sold because he needed money. When he owned the plough he ploughed all his fields. He says he will buy another if he gets enough money. He never buys inorganic fertiliser.

Table 8: Lomiyo's landholding in 1996.

Field no.	Local name	Soil type	Field history
348	hanyan kasarawa/kudu nisa	keza-keza	cultivated 23 years, but this year one half is fallowed due to labour constraints
372	kudu tsakiya / hanyan Birniwa	katikime	cultivated 23 years, but this year one half fallowed due to labour constraints.
433	kudu ta kusa	black keza-keza	purchased 10 years ago, and cultivated every year since then
509a	gabar ta nisa	tulo-tulo	more than 30 years under continuous cultivation
64	arewa / hanyan Kwubsa	keza-keza	fallow for 10 years

4.1.4 Dambage

Dambage began farming his fields about 36 years ago. He harvests crops from each field every year. He also applies manure to each field every year. Dambage doesn't own a cart but pays to hire one, and takes about 1 cart-load of manure to each farm. The exact amount varies according to the size of the field. He also pays for each field to be ploughed every year. As his children are young, he hires labour. Dambage also works as a butcher within the village.

Table 9: Dambage's landholding in 1996.

Field no.	Local name	Soil type	Field history
521b	gona gabas / gona falki	keza-keza	
644	gona yamma to ba ruwa	tulo-tulo	far from village
281	gona ta kudu	katikime	
179	hanyan sabon gari / arewa	tulo-tulo	temporary loan from Maigari

4.1.5 Kyari

Kyari practices fallow rotation to maintain soil fertility. 2-3 years ago he used inorganic fertiliser, but he now finds that this is scarce and expensive. He also used to pay cart owners to carry manure to his fields, but stopped about 4 - 5 years ago. Now, instead of manure, he rotates the cultivation of his fields, and says its just as successful.

Table 10: Kyari's landholding in 1996.

Field no.	Local name	Soil type	Field history
401	hanyan Birniwa ta nisa	tulo-tulo, near falki	5 years fallow following 4 years cultivation
439	kudu kusa	katikime	fallow 1976-1986 cultivated 1987- 1993 fallow 1994-1995
500	gabas kusa	keza-keza	2 years fallow after 7 years cultivation *
500	gabas nisa	katikime	4 years cultivation following 5 years fallow *

* *cannot weed whole field, therefore there is fallow within the cultivated field*

Kyari pays for his fields to be ploughed, especially to break the fallow. During the second season a field is under cultivation he uses the ashasha to weed the farm as the crops emerge, and ploughs later in the season.

Fuelwood is collected from both fallow and cultivated fields, but he gets more wood from fallows. He doesn't let others take fuelwood from his land.

4.1.6 Adamu

Adamu has seven fields, five of which are cultivated, and two are under fallow. He has been practicing fallow rotation around these seven fields for 40 years. Last year he took approx. 50 donkey-loads of manure to arewa hanyan Nguwa (143). He says inorganic fertiliser is too expensive. His manure comes from animals and a donkey of his own, not from communal refuse pits.

He hires a plough, to plough some of his fields, and others are cultivated with the ashasha. He gets sufficient food to meet his family's needs from farming, and only sells once the next rains have begun, if he has surplus. He also gets sufficient fuelwood from his land.

Table 11: Adamu's landholding in 1996.

Field no.	Local name	Soil type	Field history
143	arewa hanyan Nguwa	tulo-tulo	cultivated for 6 years following 7 years under fallow
184/222	arewa hanyan Lawandi	keza-keza	3 years cultivation following 8 years under fallow
484	gabas kusa	katikime	1st year under cultivation after 7 years of fallow shared with Sani Mohammed
476	gabas nisa	tulo-tulo	cultivated for 9 years after 15 years of fallow
495	gabas tsakiya	keza-keza	cultivated for 4 years following 12 years of fallow
645	arewa shaya hanyan Boursali	keza-keza	5 years under fallow following 12 years under cultivation
646	shaya hanyan Dalari	katikime	10 years under fallow following 10 years under cultivation

4.2 Monitoring of the markets

As expected, grain prices were low following harvest, and gradually increased through the dry season until dropping at the next harvest period (Figure 3). Bean prices followed a similar trend, but the price increase was more dramatic (Figure 5). Farmers became very concerned for the future when bean prices jumped to N8,000 per bag, and remained there for so long. Guna prices were only quoted when this was available in the market: from March to December (Figure 4). The high price of N2,000 per bag, which encouraged farmers to plant guna, dropped as the harvest came in. Yields of guna were high in 1996, and as the rainy season approached many trucks loaded with guna were taken to market. Unfortunately, at this time, the price per bag fell as low as N700, which was disappointing for the farmer who was relying on this financial return to buy planting seed and pay for ploughing and labourers. The sudden drop in livestock prices in July is due to a change in monitoring practices: from quoting the price of a prize animal, to quoting the price of an average animal (Figure 6). Taking this into account, livestock prices did not vary as much as grain prices.

Labour prices during the 1996 rainy season were N 140 per day. For farmers who sold their grain after harvest in 1995, one bag of sorghum was equivalent to approximately 5.7 man-days of labour, and one bag of millet was equivalent to 7.5 man-days. If they delayed selling until May, the terms of trade became more favourable to them. If they were fortunate enough to be able to delay sales until August, one bag of sorghum was worth 12.5 days of labour, and 1 bag of millet, 14 days of labour. At these prices, 4-5 bags of millet would purchase a cart.

Figure 7 shows how the value of the farmers' excess grain varies after the harvest. This was calculated by assuming that farmers' require 200 kg grain per member of their family to meet their family's food needs (Simmons, 1976), and that any grain in excess of this may be sold. In practice this is a crude estimate, as farmers often sell more grain at harvest time, and then buy back grain later in the season, when the price is higher. The graph is based on millet and sorghum sales only.

Figure 8 shows that farmers' yields vary considerably. Excess grain produced is dependent on farmers yields, and also family size. Grain production per household can be seen in Table 12, which shows that all six farmers are producing more grain than they need to feed their families. However, a farmer such as Lomiyo does not produce as much excess grain, and therefore cannot raise as much cash as the others. Farmers who produce more grain are able to sell some bags at harvest time, to meet immediate needs, and save a few until prices are higher, perhaps to fund the purchase of seeds in May, labour for land clearing and ploughing in June, a bag of fertiliser, or agricultural labour during the rainy season to assist with weeding and harvesting. At harvest time, Dambage's excess grain sales were equivalent to 41 man-days of labour, whereas Lomiyo's were only equivalent to 8 man-days. Even at the time when prices were highest, Lomiyo's sales would not provide much money for investment into his farming, for example, the repair of his cart.

Of course, the reason why prices are increased at times is due to lack of availability. Most farmers cannot store their excess grain until 10 months after harvest, because they need money sooner. Even though they get less money, they sell earlier in the year. Another potential problem is storage pests, which affect beans, and possibly one or other of millet and sorghum. Farmers are reluctant to risk the loss of the grain by pests while waiting, hopefully, for further profits.

The advantage of growing guna is that it produces a harvest which is potentially very valuable just at the end of the dry season, when most farmers do not have much left to sell.

Figure 3: Market price of millet and sorghum, November 1995 - December 1996.

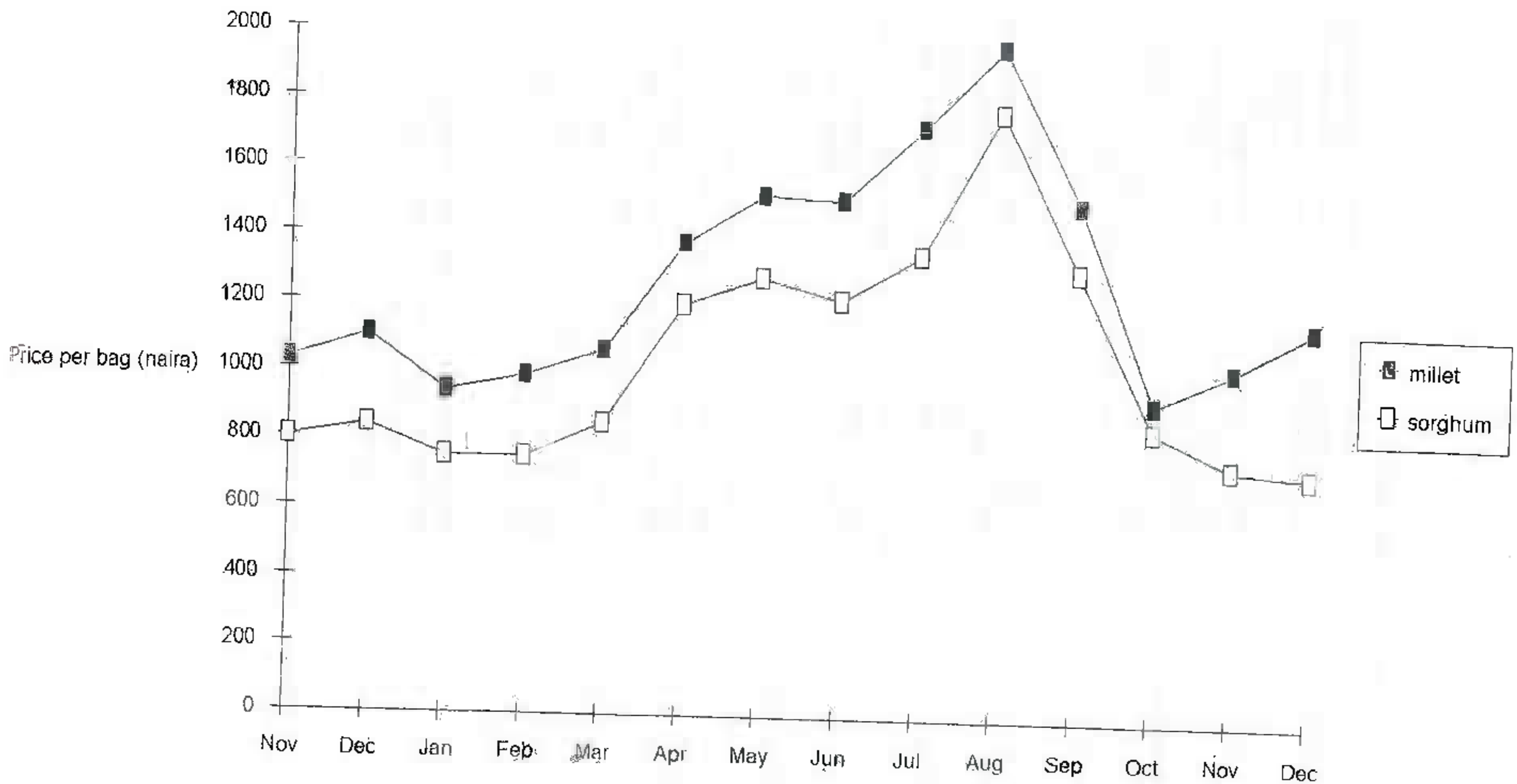


Figure 4: Market price of Guna, October 1995 - December 1996.

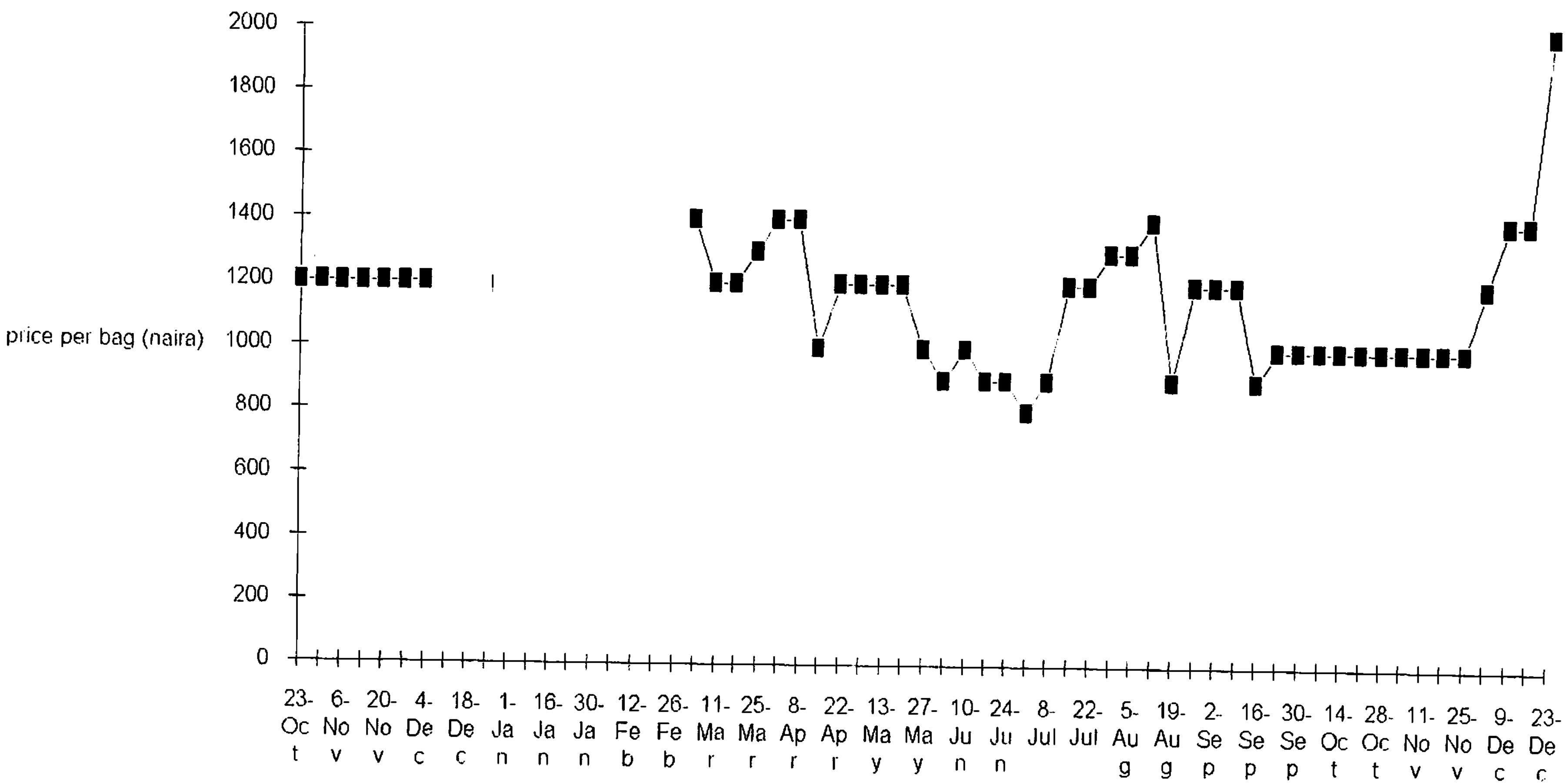


Figure 5: Market price of beans, November 1995 - December 1996.

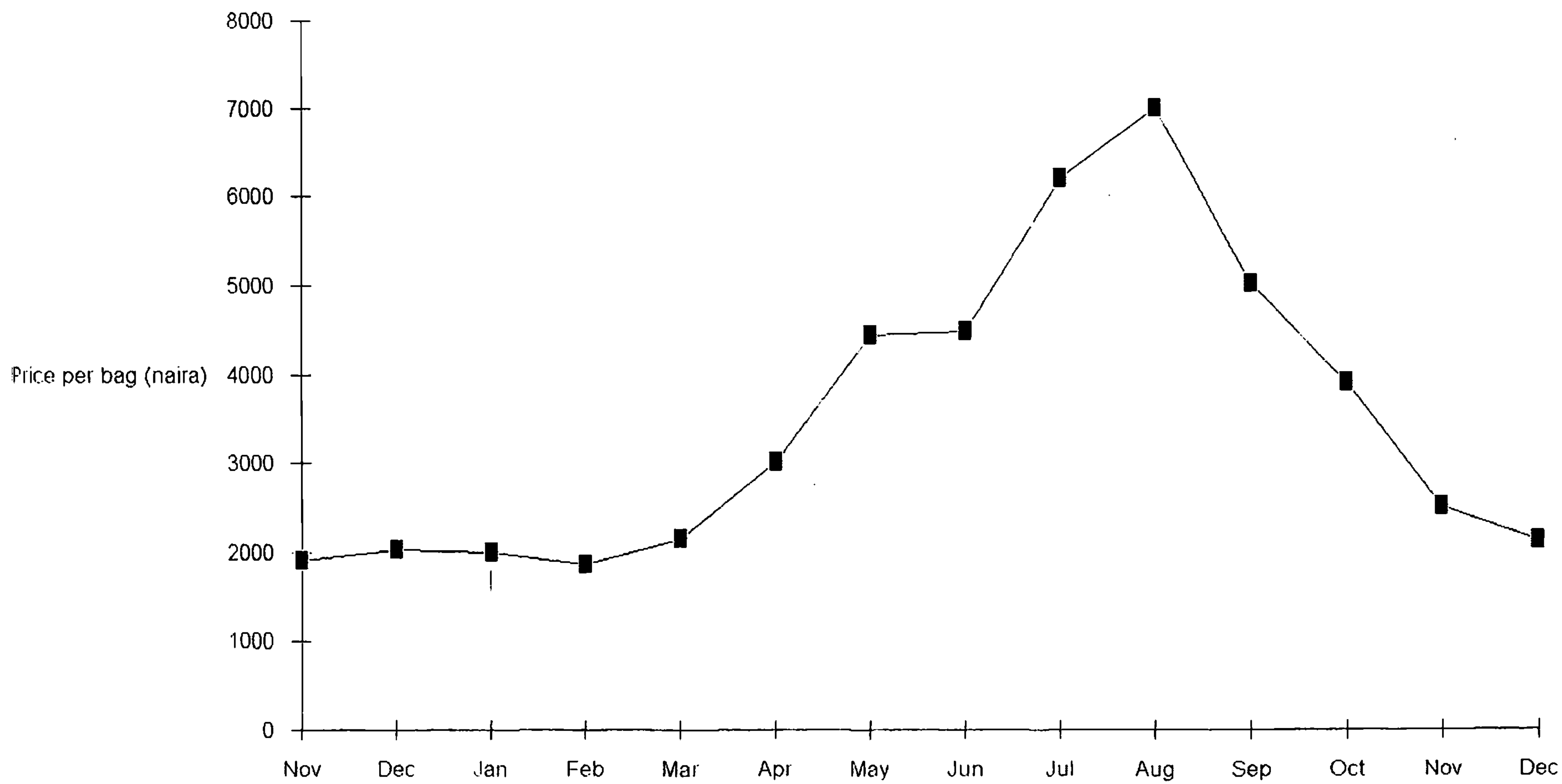


Figure 6 : Livestock prices, April - September, 1996.

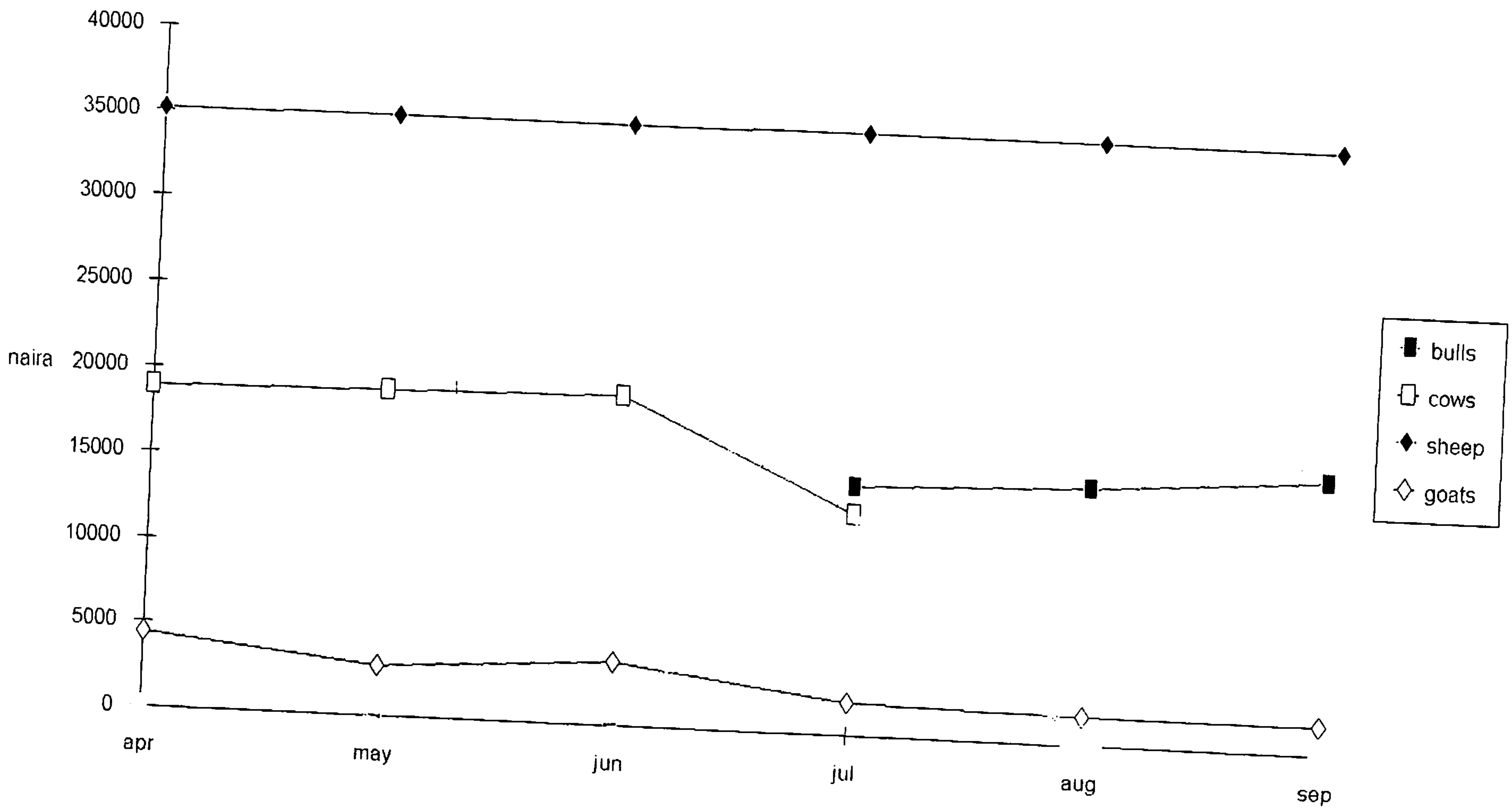


Figure 7 : Potential value of harvest, November 1995 to September 1996.

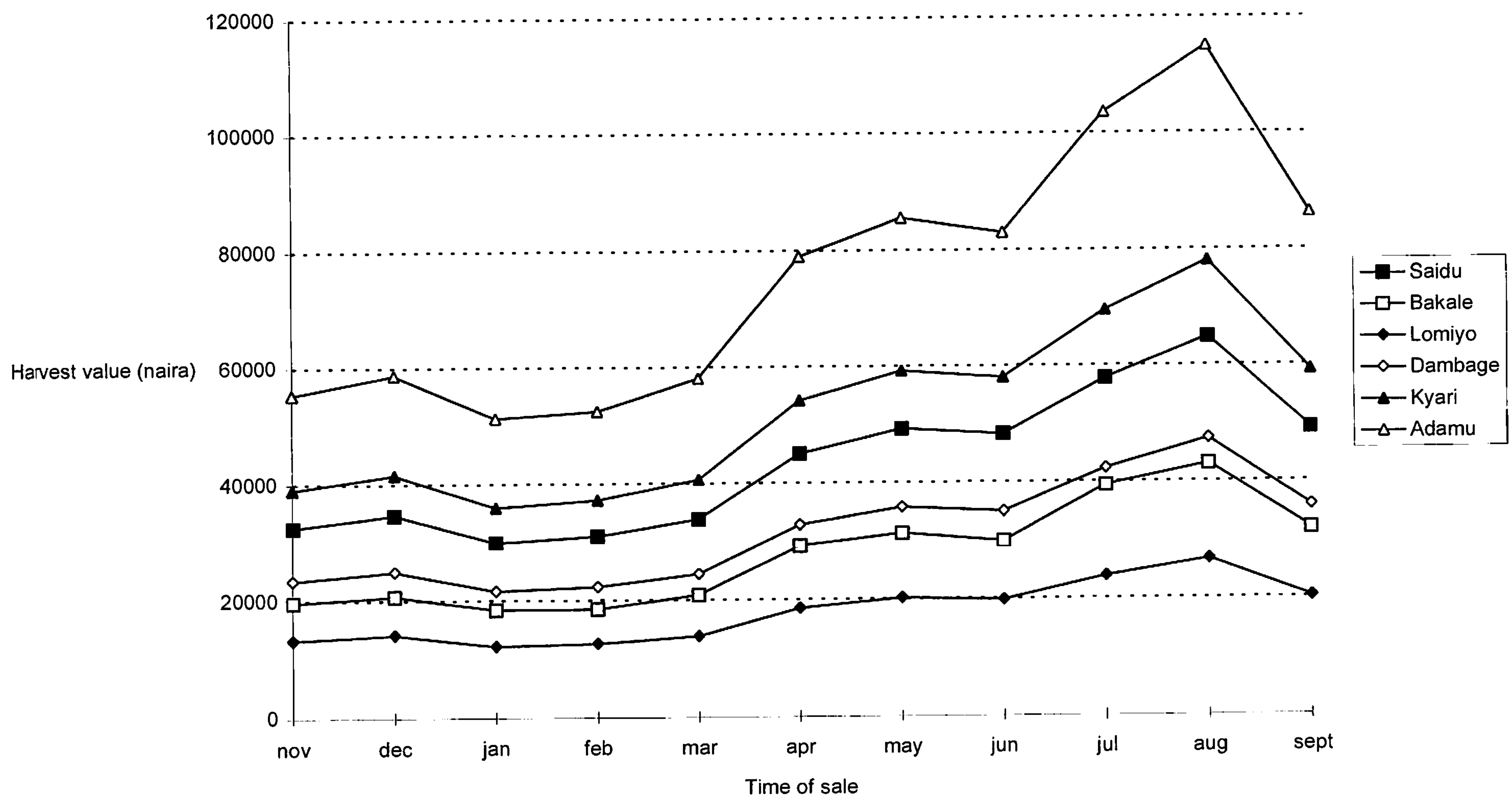


Figure 8: Comparison of farmers' yields.

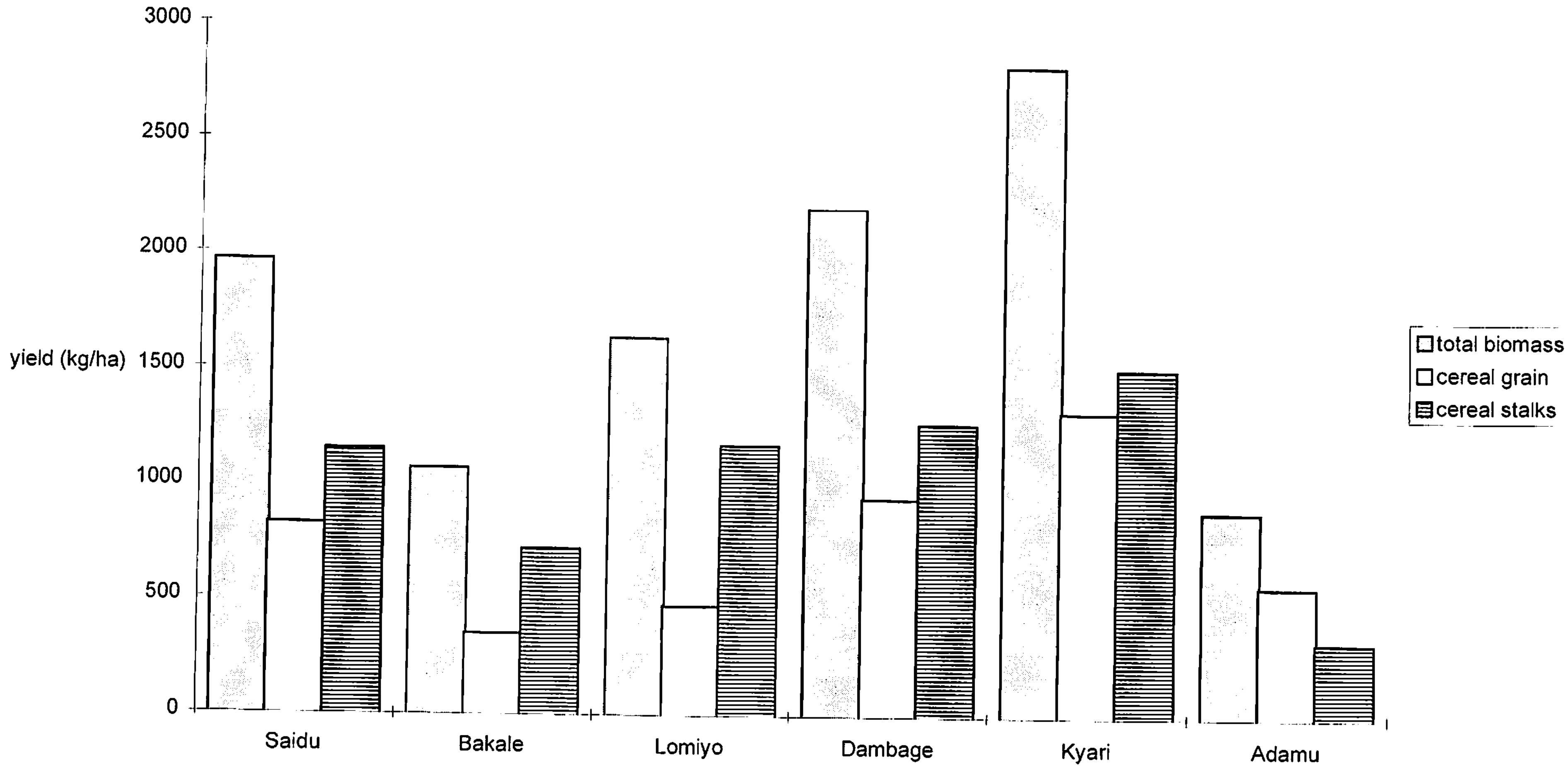


Table 12: Grain production by the farmers' studied.

Household	size (persons)	grain yield (kg)	grain per capita (kg/head)
Saidu	9	4995	555
Bakale	5	3301	660
Lomiyo	3	1870.5	623.5
Dambage	8	4023.5	503
Kyari	4	4670	1167.5
Adamu	4	6637.5	1659

4.3 Nutrient Dynamics

4.3.1 Sources and Sinks of Nutrients

There are several sources of nutrients which may be applied to farmers' landholdings. They include manure from compounds, manure from grazing animals, compound refuse, inorganic fertiliser, Harmattan dust, biological nitrogen fixation (bnf), and the passive fallowing of fields.

Figure 9 shows the relative importance of these sources of nutrients in the farmers' soil fertility management strategies. It is immediately noticeable that three farmers rely on manure as a source of nutrient inputs much more than the others. Manure provides between 80-90% of the nitrogen input and 60-70% of the phosphorus and potassium input for Saidu, Bakale, and Dambage, and approximately 50% of the nitrogen inputs to Adamu's land.

The large amounts of manure applied by Bakale and Dambage also contributed the majority of phosphorus to these farms: between 2.5-3.5 kg/ha. Dambage and Lomiyo also applied inorganic fertiliser, which provided another 1-2 kg/ha of phosphorus. The other farmers in the study did not apply inorganic fertiliser.

The Harmattan wind brought dust which contributed approximately 0.67 kg/ha of phosphorus. While in some farms (e.g. Dambage) this constituted around 20% of phosphorus input, for others, such as Lomiyo's, Kyari's and Adamu's, it was 50-60% of phosphorus input. Animals grazing on the land contributed very little phosphorus. Those who did not use manure relied more heavily on fallowing land and the Harmattan dust to supply phosphorus and potassium. Although the importance of this input is diminished when manure is used, this free input of nutrients is a significant input into farmers' landholdings.

The main source of potassium inputs is from Harmattan dust, which contributed 15 kg K/ha to the land, accounting for between 80 and 95% of potassium inputs in Lomiyo, Kyari and Adamu's land. The other farmers used significant amounts of manure, which provided 10-25 kg K/ha, and made up 40-60% of their potassium inputs. Other sources of potassium were negligible.

At present nitrogen fixation contributes only 2.5 kg/ha nitrogen to cropped farmland in the system. It constitutes 40% of the nitrogen inputs on Adamu's farm, but less than 10% of the nitrogen input on Dambage's farm. Kyari gains nitrogen from nitrogen fixation and animal grazing, but his main source of nitrogen (60%) is from fallowing land. Inorganic fertiliser provided 30% of the nitrogen input to Lomiyo's land. The one bag of inorganic fertiliser

Figure 9: Sources of nitrogen, phosphorus and potassium

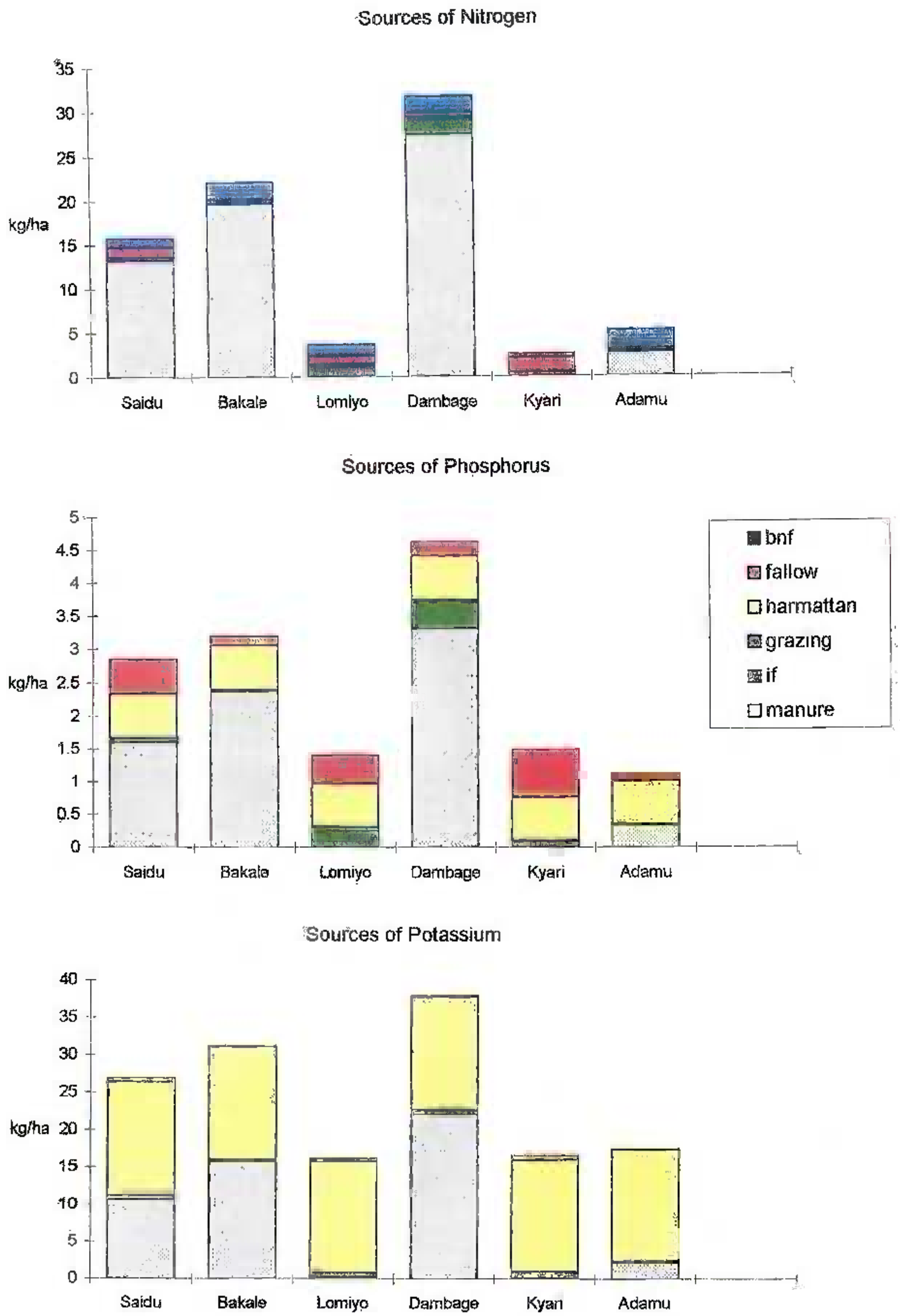
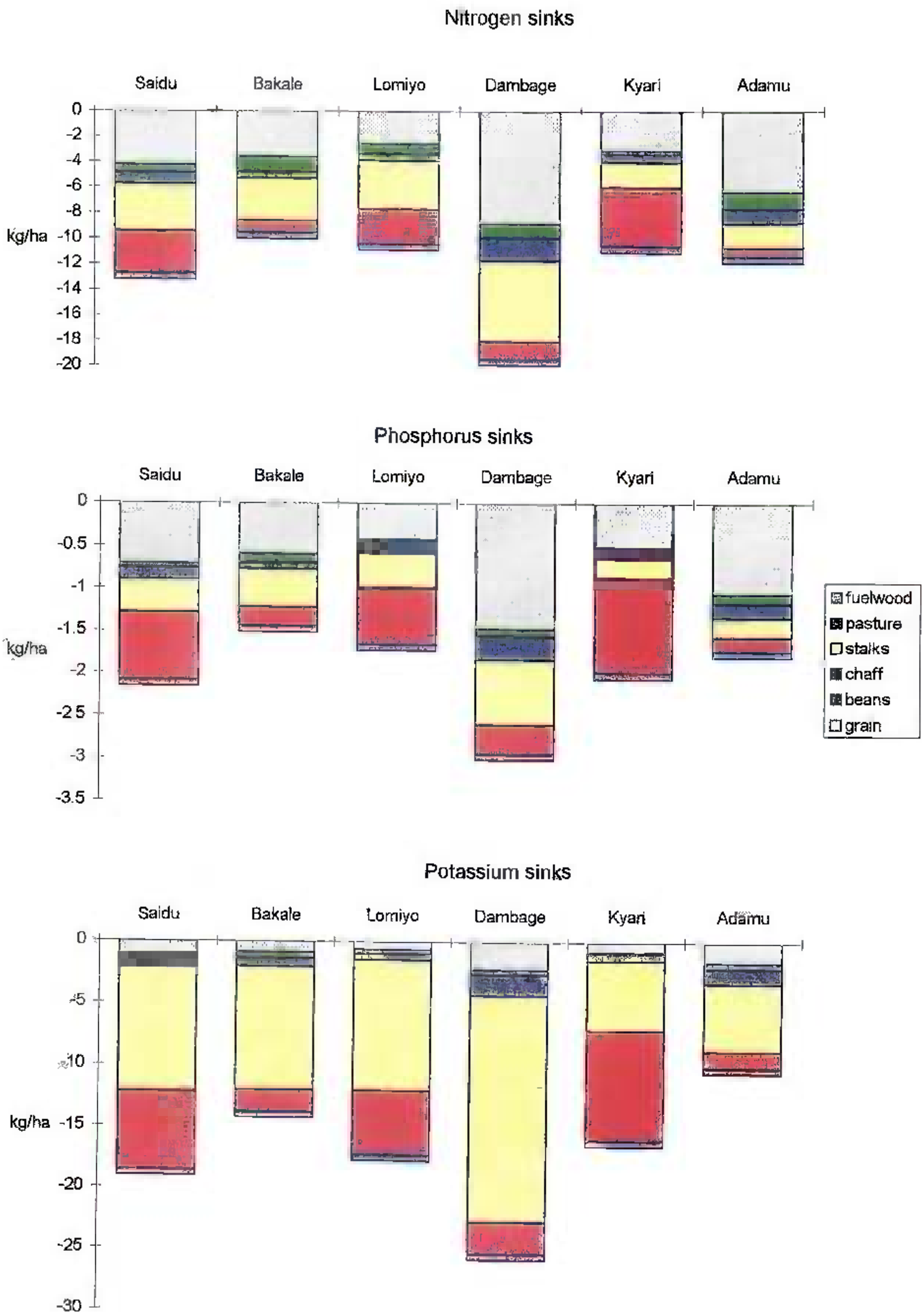


Figure 10: Sinks of nitrogen, phosphorus and potassium



purchased by Lomiyo provided inputs of nitrogen more or less equal to the fallow and nitrogen fixation, but he was very dependent on Harmattan dust for phosphorus and potassium inputs.

The destinations of nutrients that are applied to fields are considered in Figure 10, where nutrient sinks are identified. Nutrients are lost from the farmers' landholdings through the harvest of crops and crop residues. Grain harvest accounts for 25-50% of nitrogen losses from the land, and stalks for slightly less. Beans accounted for less than 15% of nitrogen losses, fuelwood for about 5%, and pasture from 5-25%. Dambage had the largest nitrogen losses, due mostly to cereal grain and stalk harvest. Even for Saidu's land (a Fulani pastoralist), losses in grain and stalks outweighed nitrogen losses from grazed pasture. Kyari had the largest nitrogen losses from grazed pasture.

Phosphorus removed in harvested grain ranged between 0.5 and 1.5 kg P/ha, and was highest for Dambage. This accounted for between 25 and 60% of phosphorus lost. Stalks removed between 0.5 and 1.0 kg P/ha, equivalent to 15-30% of phosphorus removed. Dambage had the highest phosphorus losses, and Bakale the lowest. Phosphorus losses from grazing pasture were also significant: up to 1.5 kg/ha for Kyari, and making up between 10 and 50% of phosphorus losses.

The largest remover of potassium was cereal stalks, which took between 5- 10 kg K/ha, 40-75% of potassium removed. Grazing or pasture land was the second largest sink of potassium.

This discussion is summarized in Table 13.

Table 13: Main sources and sinks of nutrients, in order of importance.

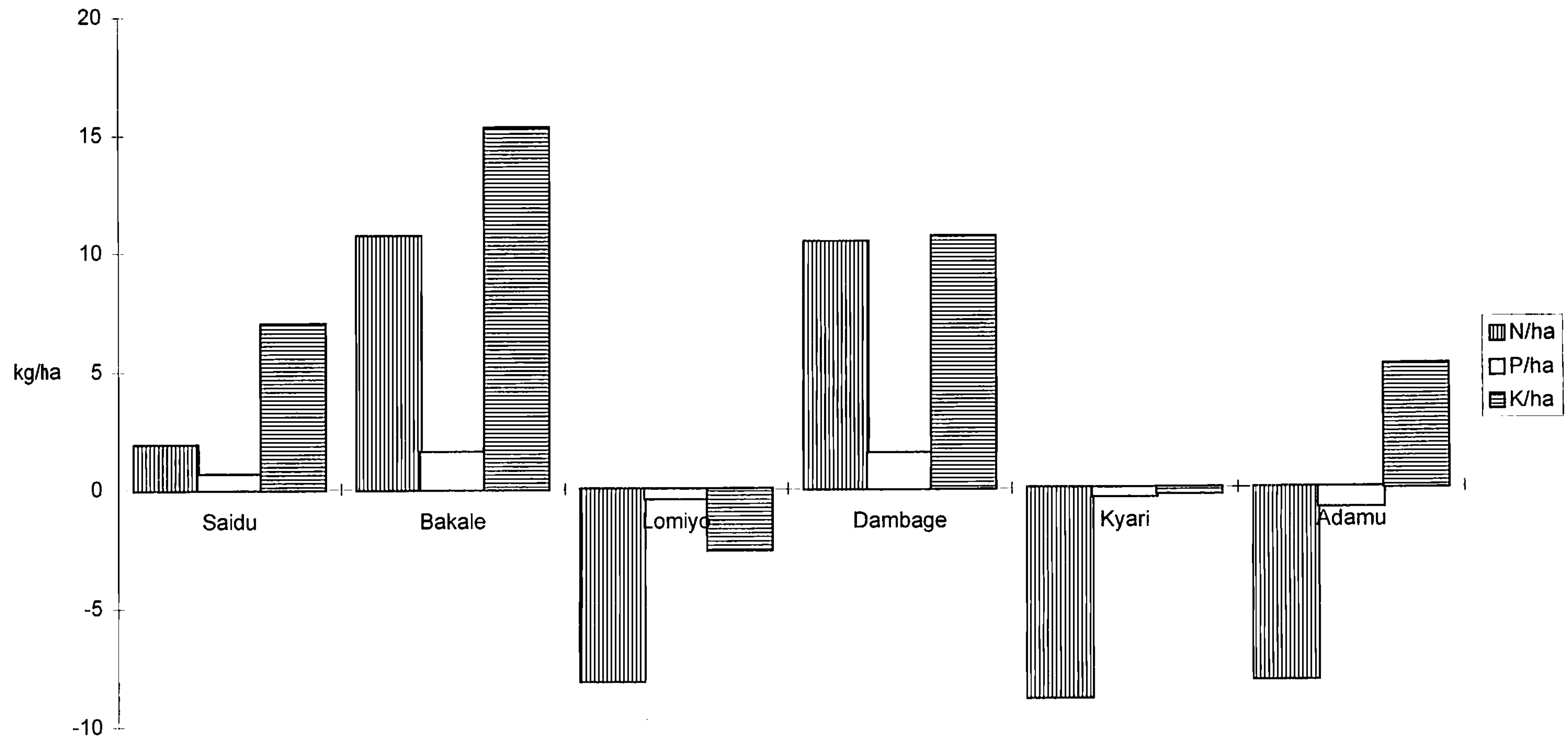
	nitrogen	phosphorus	potassium
gains	manure	manure	Harmattan
	fallow	inorganic fertiliser	manure
	nitrogen fixation	Harmattan	
		fallow	
losses	grain	grain	stalks
	stalks	stalks	pasture
	pasture	pasture	

4.3.2 Nutrient balances of farmers' landholdings.

Figure 11 presents the nutrient balance of the farmers' landholdings, which includes their fallow and cultivated fields. Nutrient inputs and outputs are measured across these field boundaries. Livestock are outside of the boundary, even thought they can walk onto and off of the fields. Therefore what they eat is counted as an output, and what they deposit, as manure, is counted as an input. Likewise, manure that is deposited in the compound at animal tethering points, and possibly left on village refuse heaps, is outside of the system, but returns to the system when it is applied to fields as donkey- or cart-loads of manure. The specific calculations can be seen in Appendix 1.

Figure 11 indicates that the nitrogen balance varies from +10.70 to -8.82 kg N/ha, the phosphorus balance varies from +1.57 to -0.81 kg P/ha and the potassium balance varies from +15.28 to - 2.57 kg K/ha. Figure 11 shows that farmers such as Saidu, Bakale and Dambage appear not to be mining their farmland. However a farmer such as

Figure 11: Nutrient balance of farmers' landholdings.



Lomiyo could not be expected to continue farming his land forever if the present year is typical of general practice. Bakale had the most positive balance of each nutrient of all 6 farmers, followed by Dambage. Lomiyo had the worst balance, although Kyari and Adamu had lower nitrogen balances. and Adamu also had a lower phosphorus balance.

4.3.3 The nutrient cycle

Previous work has shown how nutrient balances can vary considerably from year to year, as a result of changes in rainfall (Harris, 1998). The value of calculating a nutrient balance is not so much in the balance itself, which is a picture of one year only, but in the fact that the preparation of the balance involves collecting detailed knowledge providing information on nutrient flows in the farming system, and the quantification of those flows.

Figure 12 shows a nutrient cycle which describes the nutrient flows within the farming system. From it, one can see that the nutrient balance described is a part of a larger nutrient cycle. While landholders in the area may consider themselves to be either farmers or herders, all keep livestock and grow crops. Almost all livestock (i.e. cattle and small ruminants, with the exception of donkeys and oxen) spend some time grazing rangeland, and have their diet augmented with crop residues. All farmers operate a nutrient management system where crop and livestock production systems interact. The nutrient cycle is applicable to all farmers in the area, although each farmer may emphasize different aspects of the cycle in his particular nutrient management system.

The soil component of the system is composed of cultivated fields, fallow fields and rangeland. These categories are, in part, interchangeable, as cultivation is rotated between fields, which go into and out of fallow, and as agricultural expansion can bring rangeland into cultivation. Fields that are fallowed for long periods may effectively revert to rangeland. especially if they border on rangeland or cattle tracks, as some of Kyari's fields do. Some fields are cultivated annually, especially those close to the village. Longer-term studies (Mortimore and Adams, 1997) have shown the dynamic nature of this categorization. In a similar way, vegetation grown varies as the land changes classification from rangeland to fallow and to cropland.

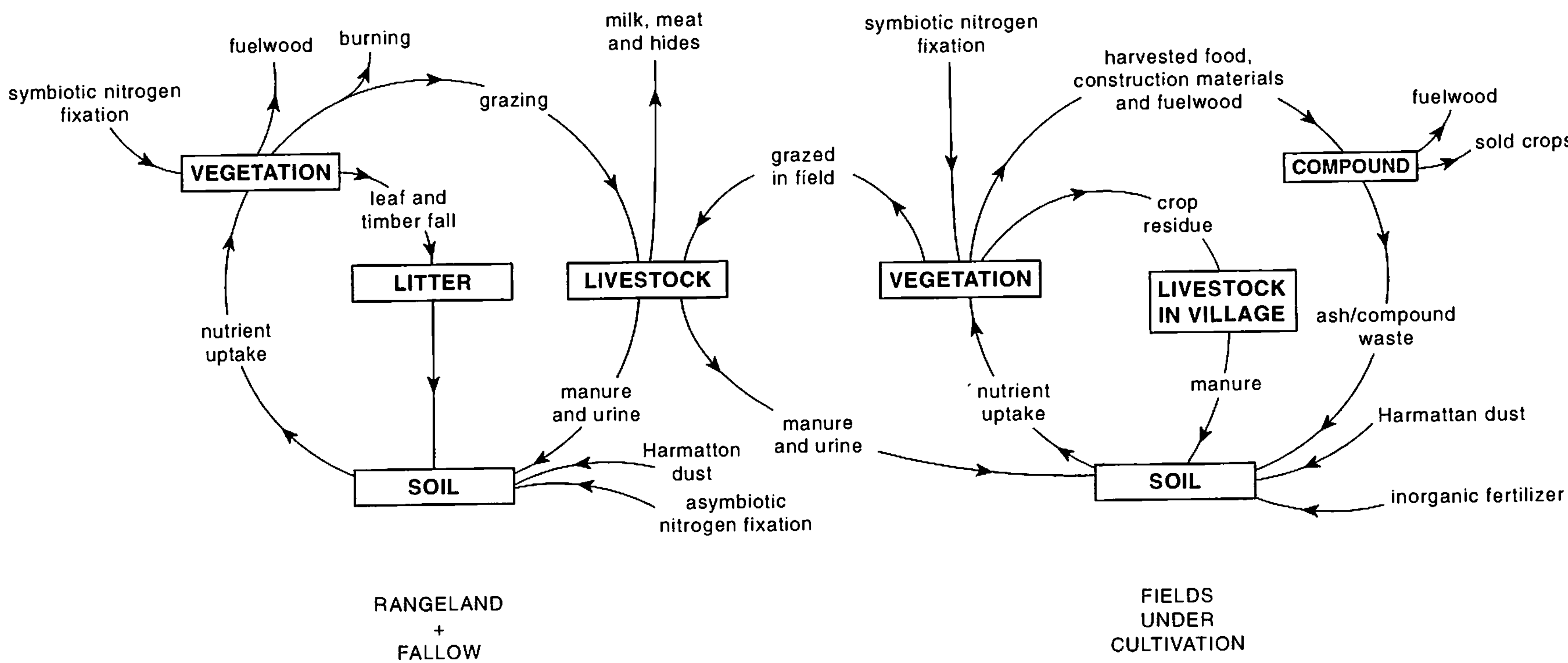
The input/output balance concerns the farmers' landholdings, i.e. their fallow and cropped fields depicted in the lower right of Figure 12. The balance calculations show that some of the farmers are managing to maintain a positive balance on their landholdings, whereas others are not.

The analysis of sources of nutrients shows the importance of manure as a source of nutrients. Figure 12 indicates that some of the nutrients in manure may come from rangeland. Rangeland vegetation is grazed by livestock, who later deposit manure on farmers' fields (a fairly small transfer, relatively speaking) or who return to farmers' compounds, where they are tethered overnight. Here, animals leave larger amounts of manure, which can be transported to the fields which farmers are cultivating. Considering the relative areas under rangeland and cultivation, and the production of livestock feed on either (grasses and herbs, or crop residues), it seems that more of the livestock feed intake comes from rangeland and fallow fields than from cultivated fields. Figure 12 shows how nutrients consumed in vegetation in the rangelands can end up as nutrients applied to the farmers' fields as animals manure. Therefore there is a net import of nutrients from the rangeland to farmers' landholdings.

At harvest time, grain is taken to the storage granaries, and later threshed. The chaff may be combined with other waste material such as cooking waste and compound manure and be applied to fields as fertiliser. Grain is consumed by the family, and any excess may be sold in the markets, and so the nutrients contained in the exported grain are exported from the system. Beans are also harvested and threshed, and most are sold immediately. Beans are often attacked by pests and therefore farmers usually sell beans on to wholesalers immediately, rather than run the risk of losing them to pest damage, and being left without anything to sell. The haulms of bean plants are left in the field. and usually rot. Millet and sorghum stalks are collected in the field in stooks, and may be used as livestock fodder, sold to Fulani who require fodder for their cattle, or as fuelwood (in which case nitrogen is lost, phosphorus and potassium are recycled as ash).

During the dry season, livestock may graze rangeland, fallow land and fields. In some years some farmers grow guna melon. in which case access to fields by livestock is limited, as fallow fields my be enclosed by fields on

Figure 12: Nutrient cycling in Dagaceri village.



which guna is growing, so prohibiting grazing of these fields too. However once the guna is harvested, livestock will graze such enclosed fields. Prior to the rainy season, farmers engage in field clearing. Shrubs, especially Boscia senegalensis, Gueira senegalensis and Hyphaene thebaica are cut to ground level. Thus some nutrients are recycled through the farmers' compound, some are exported, and some are imported as inorganic fertiliser, by nitrogen fixation, or in the Harmattan dust. The farmer tries to be the manager of the nutrient flows, however his ability to manipulate the nutrient flows within the farming system is affected by constraints, such as labour availability and cost.

4.4 Strategies to gain nutrients

The different strategies used by farmers to gain the main three nutrients important to maintain soil fertility are clearly seen in Figures 9 and 10, and summarised in Table 14. Saidu relies on corralling cattle, and the manure they supply for his farmland. Dambage and Bakale manure their land intensively. Adamu does manure some of his land, but tends to rely on fallowing land, as does Kyari. Both Lomiyo and Dambage used inorganic fertiliser.

Table 14: Soil fertility maintenance strategies of the six farmers.

Farmer	Strategy
Saidu	corralling of cattle herd on farmland
Bakale	intensive manuring
Lomiyo	inorganic fertiliser
Dambage	intensive manuring and inorganic fertiliser
Kyari	fallowing
Adamu	fallowing

Factors affecting the acquisition of nutrients from each source are discussed below:

4.4.1 Animal manure

The easiest way to get animal manure onto land is to allow animals to graze the land and hope that they will deposit manure onto the fields at the same time.

Although the village does in theory allow common access to fields during the dry season, and to fallow fields during the cropping season, this does not work out in practice. Access to fields may be influenced by cropping of guna in the dry season, which can prevent access to fields, or the presence of wells, which attract livestock on regular watering trips.

Fields left fallow in the rainy season are not accessible by livestock if they are surrounded by cropped fields. Almost all stalks (the exception being those of poor quality from failed crops of millet and sorghum) are cut and stored in stooks on the fields, placed in such a way that livestock cannot graze them. Farmers save enormous stooks of stalks, waiting for the price to increase before selling them to Fulani. These farmers may have no need of the residues themselves, but delay selling until they can maximize their profit. By growing guna, farmers limit Fulani's traditional access to crop residues in fields. This creates a better market for the farmers' crop residues. In years of poor rainfall, farmers harvest the grass from their fallows in bundles and sell it to the Fulanis.

In other areas of Africa, exchanges of crop-residues for night parking of cattle on a field are made (Schlecht, 1995, Powell, 1986) but this does not occur in Dagaceri. Instead, the Fulani corral their animals on their own farmlands, rotating the position of the corrals regularly, and ensuring well-manured farmlands of their own.

Like the Fulani, farmers who need a lot of fodder to feed their animals may begin to save their crop residues to feed their own animals. Transporting the cop residues to the compound is laborious, and requires a cart of donkey. Those farmers who do this still send their animals out for daily grazing from common access lands with the village herder, but have effectively stopped contributing their crop residues to the pool of common access resources. The manure produced within their compound is then transported back to their fields. Adamu does this, and Bakale, to some extent.

4.4.2 *Refuse heaps*

Compound sweepings are carried to refuse heaps located along roadsides just outside the village. These heaps grow during the year, but prior to the rainy season many farmers collect the refuse and take it to their fields to fertilize the soil.

A farmer's ability to appropriate this communal resource and transport it to his own fields varies according to his with wealth (ownership of transport), labour availability, and distance of his fields from the village.

Farmers who own carts, such as Bakale, can take more of the manure from refuse heaps than those without a cart or donkey. Thus they can take a larger portion of the common access nutrients, resulting in a re-distribution of nutrients towards those land owned by transport-owning farmers.

A farmer who doesn't own much livestock can still take a disproportionate amount of the waste from the common access refuse heaps to his fields if he owns a cart of donkey with which to transport it. Those without a cart but who can afford to hire one can also do the same. One way of raising such money would be to sell the crop residues from the fields to Fulani. Common access nutrients become privately owned.

Wile some farmers seem to operate solely cropping systems, other have integrated crop and livestock production within their household, so that all the nutrient flows fall within one management unit. Now integration of production is beginning to occur all groups are competing for the same resources. The farmer's aim is must be to try to bring as much of the common access nutrients to one's own farm, while donating little to the refuse pits. The constraint will be labour.

4.4.3 *Biological nitrogen fixation and legumes*

The most obvious way to increase nitrogen inputs at low cost is through increasing nitrogen fixation. The present input is extremely low, mostly because farmers plant very few beans. Farmers could increase nitrogen fixation by planting beans more densely in the fields. Giller and Wilson quote examples of nitrogen fixation by Vigna unguiculata in Nigeria reaching 47-120 kg N/ha. While farmers may not be able to achieve such high rates of fixation, a more likely achievement of an input of 25 kg/ha would still have an important effect on the nutrient balance, as none of the farmers' balances were lower than -10 kg/ha. As well as increasing nitrogen fixation, bean cultivation would have several effects, such as

1. provide greater harvest of a valuable and nutritious crop.
2. potentially provide greater cash income.
3. provide nutritious fodder for animals, who would convert it to manure.

Thus there are gains to be made, but at a cost: labour. This cannot be overlooked, and any programme to promote bean cultivation should also address factors such as:

1. increased labour needed to harvest beans over a period of time.
2. increased labour and transport needed for collecting residues.

One possible solution might be to plant the beans densely in one or two fields, so that the amount of time spent travelling to harvest them would be reduced. The beans could be rotated around farmers' fields. Perhaps farmers could plant beans on fields which weren't manured. Unfortunately farmers would be tempted to plant fields close to home with beans, which are the same fields that receive more manure too.

If farmers were to adopt the practice, common elsewhere, of harvesting and storing the haulms for animal fodder, they would require some mechanism for transporting the bundles of haulms back to the compound, or an alternative safe storage place. Cereal stalks can be piled in the field in such as way so that animals cannot eat them, and so safely stored there. This is not possible with cowpea haulms, thus transportation to a safe storage place would be necessary.

4.4.4 Fallowing

The balance of inputs and outputs for fallow land was calculated, under two conditions. 1. functional fallow: land that is not cultivated, but still grazed and used for fuelwood, and 2. pure fallow: land that is neither cultivated nor grazed nor harvested for fuelwood. (Table 15). The nutrient balance for a functional fallow is negative in nitrogen, thus this sort of fallow under which his land is at the moment is not restoring nitrogen to his land. As a functional fallow is what is in operation in most of the area around Dagaceri, then it is clear that nitrogen must be contributed to the system from outside.

4.4.5 Inorganic fertiliser

In 1996 black-market sales of inorganic fertiliser were banned, and government organized its distribution. After the onset of the rainy season, the village's allotment of inorganic fertiliser was duly delivered. Unfortunately there were complaints that this was less than what former would normally have required. Farmers make up the shortage by using manure a other organic waste. While this policy may not be repeated in future years, it is generally felt that fertiliser is expensive, and is also not always available. Hence the importance of increasing nitrogen inputs the farming system, and at low cost.

4.4.6 Assessment of the effects of the strategies

Table 16 shows the effect various recommendations might have on the nutrient balance. From this table it is clear that the Harmattan plays an important role in the phosphorus and potassium balances, and that without the Harmattan, four out of the six farmers would have negative phosphorus and potassium balances (as opposed to three with negative phosphorus balances, and two with negative potassium balances).

Table 16 also considers the effect of increasing all the inputs on all farmholdings through the distribution of one bag of NPK 27:13:13 to each farmer. While the nutrient balances would be increased, the effect overall would not be very great.

The estimate of nitrogen fixation by the N-difference method is very crude, and it is acknowledged that the result of 2.5 kg N/ha could vary from 0 - 5 kg N/ha. Variance within this range would not alter the number of farmholdings with positive or negative nitrogen balances. Literature reports of nitrogen fixation reaching 50 kg/ha in semi-arid areas are common (Giller and Wilson, 1991). If this could be achieved in Dagaceri, the nitrogen balance of all the farmers would become positive. A higher nitrogen balance would increase crop yields, and so have an effect on the whole nutrient balance and nutrient dynamics of the farming system.

Table 15: Nutrient gains and losses in fallow land.

Inputs	amount (t/ha)	% N	N (kg)	%P	P (kg)	%K	K (kg)
Grazing animals	76.8	0.82	0.63	0.15	0.12	1.51	1.16
Harmattan	740	0.00	0.00	0.09	0.67	2.03	15.02
Fallow land			2.00		0.90		0.83
Outputs							
pasture grasses	1259	0.45	5.67	0.11	1.38	0.87	10.95
shrubwood	202.5	0.26	0.53	0.04	0.08	0.27	0.55
Inputs-Outputs			-3.56		0.22		5.51
Sum enclosed fallow			2.00		1.57		15.85

Table 16: Assessments of the effects of interventions

		N/ha	P/ha	K/ha
Normal				
	Saidu	-2.59	0.63	12.40
	Bakale	4.06	1.57	23.34
	Lomiyo	-8.10	-0.40	-2.57
	Dambage	1.18	1.50	21.88
	Kyari	-8.82	-0.36	-0.25
	Adamu	-8.98	-0.81	6.33
No Harmattan				
	Saidu	-2.59	-0.03	-2.62
	Bakale	4.06	0.91	8.32
	Lomiyo	-8.10	-1.07	-17.59
	Dambage	1.18	0.83	6.86
	Kyari	-8.82	-1.03	-15.27
	Adamu	-8.98	-1.48	-8.70
1 Bag 27/13/13 (50 kg) added to each existing system				
	Saidu	-1.67	0.79	12.76
	Bakale	5.16	1.76	23.77
	Lomiyo	-6.60	-0.15	-1.99
	Dambage	3.55	1.89	22.80
	Kyari	-8.01	-0.23	0.07
	Adamu	-8.16	-0.68	6.65
BNF by beans is 5 kg/ha				
	Saidu	-1.55		
	Bakale	6.15		
	Lomiyo	-6.80		
	Dambage	3.07		
	Kyari	-8.34		
	Adamu	-6.78		
No BNF				
	Saidu	-3.64		
	Bakale	1.97		
	Lomiyo	-9.41		
	Dambage	-0.71		
	Kyari	-9.30		
	Adamu	-11.19		
BNF=50kg/ha (lower end of scale in references in Giller and Wilson, 1991, pg 127.)				
	Saidu	17.25		
	Bakale	43.84		
	Lomiyo	16.70		
	Dambage	37.01		
	Kyari	0.23		
	Adamu	32.88		

4.5 Labour

Labour is a very important component of this farming system, and affects which strategy to conserve soil fertility can be used by farmers. Landholding sizes are large, and farmers have to travel long distances to deliver any inputs to the fields, or to collect any material harvested from them. As populations increase and farmholdings are divided with each generation, farmholdings will decrease in size, however individual fields may still be distant from the village. One of the attractions of owning a cart is simply to enable farmers to drive to more distant fields, and arrive sooner than if travelling on foot. It also enables farmers to carry more drinking water with them, so that they can stay in the field all day, rather than returning to the compound. Carts also enable farmers to harvest crop residues for livestock fodder, and take manure to fields, which are important activities to maximize nutrient recycling and conserve soil nutrients within the farmholding.

Table 17: Labour use by farmholdings.

Farmer	Farm Labour (man-days)	cultivated area (ha)	Farm labour input (man-days per hectare)	Hired labour	% of farm labour hired in
Saidu	404	6.1	66.2	60	15
Lomiyo	635	4.7	135	11	1.7
Kyari	1454	3.18	457	107.2	7.3
Adamu	1071	14.49	74	330	31
Dambage	1399	4.29	326	68	4.9

Those farmers with larger families have more labour available (Table 17, and Table 1). However larger family's often require more household work as well. Farmers such as Dambage and Saidu had more man-equivalents of family labour available (1.2 and 1.1) than Lomiyo and Kyari (0.5 each) and Bakale and Adamu (0.2 each). Dambage, who farmed a relatively smaller amount of land, had a higher labour availability per hectare, whereas Bakale, who farmed a large amount of land, had less family labour to help him. Saidu and Adamu who hired the most labour. Saidu was sick during 1996, and needed to hire labour to get his harvest in. Adamu hired 30% of the labour which worked on his farms, possibly because his family was small, and as he farmed such a large area, he needed the extra manpower. Those who farmed more land needed more hired labour.

Labour inputs per hectare are based on monitoring of activities of all members of a family. Input was weighted according to age and sex. Only farming tasks were considered here. Labour inputs per hectare were highest for Kyari, followed by Dambage, and lowest for Saidu, with Adamu also using little labour per hectare. The labour inputs per hectare correlate well with farmers' yields per hectare, for the four farmers. Saidu seems to get higher yields for less labour, and this may be due either to the reduced labour required for fertilizing soil, as his livestock manure the soil, and also be an artefact of the data collection procedure: he lived apart from the village, and was only monitored in 1996. Thus his ability to recall labour inputs, as well as the frequency of visit by the data recorder, may have resulted in his labour inputs appearing lower than they really were. The data show that availability of labour corresponded with manure input, and also better nutrient balances.

4.6 Alleviating the constraints to farming system

Some of the strategies to conserve soil fertility that are adopted by farmers require high labour inputs, others require financial investment, be it to purchase a cart, or purchase fertiliser. Farmers with larger households have less need to hire labour than those with smaller or younger families. The value of the harvest, relative to the cost of purchasing or applying inputs, can affect a farmers' choice of strategy to be used.

4.6.1 Labour

As already stated, labour is a big constraint to this farming system. Often fields are distant from farmers' households and travelling to and fro, particularly if transporting manure and crop residues, is time consuming. As time goes on and landholdings are subdivided on inheritance, landholdings will become more dispersed, and this transport problem will gain importance. As in the Kano close-settled zone, the provision of transport such as donkeys or carts and oxen would make a considerable difference to the farming system.

The sensitivity analysis showed that increasing inorganic fertiliser use would have little effect on the balance. As inorganic fertiliser prices are now very high. (N150-200 per bag in 1996, but more than N1000 per bag in 1997), it is unlikely to be an option which farmers could consider. The money could be better spent on a cart or donkey, which would equip farmers to engage in nutrient cycling for many years.

The example of Bakale shows how the ownership of a cart can enable a farmer to fertilize fields and so improve the nutrient balance. His cart cost N8,000, a considerable capital investment for a farmer. Yet other development projects have promoted the use of carts, and this, or the use of donkeys, could be beneficial in this area too. If transport were provided, there would be greater recycling of nutrients, including, possibly, the harvest of bean haulms for animal fodder.

4.6.2 Crop storage

If increased growth of beans is to have an effect on family nutrition, farmers would need to be able to store significant amounts of what they grow, to last them through the year. At present, they are sold to large-scale stores, and then bought back as needed, because pests often destroy improperly kept beans.

Dagaceri already has and manages a grain bank, with great success. This is maintained to ensure that pest damage does not occur. A community-based project to build and manage a bean store could have a tremendous effect on farmers' ability to improve family nutrition. It would need to make a small charge to users, to cover construction and running costs, but would allow them to either store beans for family consumption, or even for later sale on the market, when prices are higher.

Proper grain storage facilities would permit farmers to take advantage of fluctuations in market prices, rather than be subject to them. The increased revenues from their farm products would allow them to invest directly in farming, through the purchase of livestock, labour, carts and fertiliser, or indirectly, through the education of their children, and investment in non-farming economic opportunities which would provide a separate source of income, which could be invested in farming activities in times of hardship.

5. *CONCLUSIONS AND RECOMMENDATIONS (CONTRIBUTION OF OUTPUTS)*

5.1 The Fulani and Manga/Hausa systems compared.

Fulani are traditionally seen as pastoralists, and the Manga/Hausa as sedentary farmers. However, in Dagaceri, everyone is engaged in both cropping and livestock rearing. The amount of interaction between copping and livestock rearing indicates to what extent the farmers are integrating these two enterprises. After considering nutrient cycling in the farming system, it seems that both groups are feeding livestock on crop residues, although to differing extents, and using the manure to fertilize fields. Therefore both groups are involved in some sort of integrated farming system.

Livestock not only convert plant biomass into manure, for use as fertiliser, but also are the means by which the nutrients in the biomass of pastures and fallow fields are transferred from the feeding area to the area to be cropped. Thus, in a sense, they provide the labour for transportation of these nutrients as well.

In the Fulani system, cattle graze pasture land, a diet which is supplemented by cereal stalks, and are corralled overnight on the land which is to be cropped in the subsequent season. Farmers' labour to fertilize fields consists of hobbling the animals at night, herding and watering the animals in the day, and storing cereal stalks after the harvest, for feed later in the dry season. There is no need to transport stalks great distances, neither is it necessary to transport manure at all, as the livestock achieve this.

The Manga/Hausa system involves small ruminant and draft animals (donkeys or bulls). Some nutrients are gained from pasture, as the small ruminants are out grazing with the asoko during the day. Their diet may be supplemented with crop residues in the evening, at which time water must be fetched and brought to them. They leave most of their manure in the compound, which is either transported to the village refuse heap, or to specific fields. This is carried by headload, or with the use of draft animals: in panniers on a donkey, or by oxen pulling a cart. The farmers must load and unload the cart with the crop residues to be brought to the compound, and the manure to be taken to the field. Alternatively farmers may transport small ruminant manure to the refuse heap during the year, and then transport larger cart-loads of manure to fields prior to the rainy season. Not only is the transportation of the nutrients done by the farmer, rather than by the livestock, but also it requires capital expense to purchase the appropriate equipment: the draft animals, the panniers and the cart. As draft animals are never sent out to graze with the asoko or as part of a Fulani herd, farmers must ensure that there is a sufficient supply of fodder brought in from the fields to keep them, and water carried from the well, and they must also clear out the manure produced regularly.

Thus the Fulani operate a system which requires greater land per person, in which the cattle provide the labour which transfers nutrients from the pasture to the field. The Manga/Hausa have less land per person, and contribute more human labour to the farming system. They also require draft animals, which require more labour to be fed and watered, produce manure in the stall, which must then be transferred to the farmers' field. This system not only requires more labour, but also more capital outlay, to purchase the draft animals and cart.

5.2 The Future

This study presents a view of Dagaceri as it was seen in the 1996 farming season. However conditions in Dagaceri are not static, but changing. As the population increases, land is subdivided upon inheritance, giving rise to smaller landholdings. For those with larger landholdings (e.g. Bakale, Kyari, Adamu), this may mean that the new landholdings are of a more manageable] size. These farmers fallow considerable amounts of their land. Smaller landholdings would allow more labour per hectare, and less time would be spent travelling to and from the many, large fields. The relatively increased labour could be used to collect crop residues, so encouraging more recycling of nutrients within the landholding.

However for other farmers, subdivision of land may result in landholdings that are too small for the land to provide sufficient food and income for the family. Such may be the case with Dambage and Lomiyo. For these farmers, several choices are possible. They could purchase more land, if those with larger landholdings are willing, but this is unlikely. They cold borrow land from larger land owners, which would be a temporary measure, or they could turn their attention to other forms of gaining income, such as labouring on others' farms, or village industry such as butchering, which is what Dambage does at present. Dry season migration for labour (cin rani in Hausa) has been practiced in northern Nigeria for many years (Hill, 1977). A final alternative would be to sell their land, and use the money to begin elsewhere, or in a small business. This is not likely to be a popular option, as losing ones' link to land, however small a landholding, is not desirable (Hill, 1977). Thus, non-farming economic opportunities which can be practiced from the farmholding will be most desirable, and policies which support farmers in this will be valuable.

If farmers take up some of the recommendations made in this report, such as increasing legume production, they will need to increase phosphorus and potassium inputs as well. This will require more inorganic fertiliser, the cost of which could be offset by selling the higher-value grain legume crop. Increase growth of legumes would provide more highly nutritious fodder for livestock, which could compensate for reduced fodder supplier from rangeland, the result of agricultural expansion (see Mortimore et al, 1997).

5.3 Acting on the recommendations

The dissemination of the research results is important, particularly to groups operating in the area such as the Hadejia-Nguru Wetlands project, the north-east arid zone development project (NEAZDP), and Jigawa State Agricultural Development Authority (JARDA), other national agricultural research stations, as well as the wider research community. ICRISAT and IITA both have regional substations in the area, and also have a world-wide remit.

To facilitate this, a conference is being planned, in conjunction with the NRI semi-arid production systems programme, and the project Soils, Cultivars and Livelihoods, which would disseminate results within Nigeria. There are preliminary plans for a set of publications targeted to the Nigerian readership.

5.4 Dissemination outputs to date

Dissemination concerning Nutrient cycling or soil mining? (R 6603) and Nutrient dynamics of the Kano close-settled zone (EMC X0216).

Papers (presentations and publications)

Harris, F.M.A., 1997. Research on small-holder farmers in semi-arid Nigeria. Paper presented to 1º simpósio Brasileiro sobre meio ambiente e desenvolvimento sustentável do semi-árido. (First Brazilian symposium on the environment and sustainable development in semi-arid Brazil). Universidade regional do Rio Grande do Norte, Mossoró-RN, Brazil. June 3-6, 1997.

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Short presentation concerning nutrient cycling work in northern Nigeria at the British Council/SOAS meeting Renewable Natural Resources (RNR) and Environment: Northern Nigeria (The way ahead), July 14, 1997, SOAS, University of London.

Attendance at and contribution to two meetings at the Institute of Development Studies, Sussex, concerning Crop-Livestock Integration (May 23, 1997) and Soil fertility management and nutrient cycling in Africa (April 25, 1996).

Poster presentations:

Nutrient budgets in relation to indigenous farming systems in northern Nigeria. Land degradation on the edge of the Malthusian precipice. Royal Society Meeting, December, 1996.

Integrated nutrient management on farmers fields: approaches that work. Workshop convened by DFID NRSP, 15-16 Sept. 1997, at University of Reading.

Planned dissemination outputs:

Following the review of the final technical report, several shorter papers will be prepared to disseminate the information contained. The wealth of detailed data collected during both projects can provide information on issues which were peripheral to the main thrust of each project. It is the aim to compare data from both sites, to provide a series of shorter papers concerning issues raised while carrying out the research. The following titles are indicative of the content of the paper, but may be changed as the papers are prepared.

Changes in fodder availability under land use change in north-east Nigeria. For: International workshop on the biogeography of open/Savanna woodlands in Africa. 10th December, 1997, University of Leeds. (To be prepared with Mortimore and Adams).

Estimation of the nutrient balance for a short-fallow farming system in northern Nigeria.

Nutrient dynamics of a short-fallow farming system in north-east Nigeria.

Manure as an input to farming systems in semi-arid Nigeria: nutrient content, and constraints to use.

Fodder sources for livestock in intensifying farming systems.

Role of studies of nutrient dynamics in bridging the nutrient gap.

Measurement of nitrogen fixation in farmers' fields.

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Appendix 1

Calculation of the nutrient balances of farmers

Farmer:	Saidu	Year	1996	Land area (ha)	14.6
				Cultivated area (ha)	6.1
				Fallow area (ha)	8.5

Input		Amount		Nitrogen		Phosphorus		Potassium	
		kg	kg/ha	%	kg	%	kg	%	kg
Manure		15555	2550	1.24	192.88	0.15	23.33	1.00	155.55
Inorganic	20/10/05	0		20	0	4.5	0	4.2	0.00
fertilizer	20/10/10	0		22.2	0	4.4	0	12	0
	27/13/13	0		27	0	4.5	0	10.5	0
Grazing animals		652.8	76.8	0.82	5.35	0.15	0.98	1.51	9.86
Harmattan		10804	740	0.00	0.00	0.09	9.72	2.03	219.32
Fallow land		N:2, P:0.9, K:0.8			17.00		7.65		7.06
Nitrogen fixation		15.25	2.5	100	15.25				
Total inputs					230.48		41.69		391.78
Harvest	Yield	Part		Nitrogen		Phosphorus		Potassium	
	kg dm			%	kg	%	kg	%	kg
Millet	3516	grain	2321	1.80	41.77	0.30	6.96	0.44	10.21
		chaff	703	1.09	7.66	0.17	1.20	0.73	5.13
		sticks	246	1.19	2.93	0.20	0.49	1.49	3.67
	4478	stalks	4478	0.87	38.96	0.08	3.58	2.29	102.55
Sorghum	1479	grain	1109	1.79	19.86	0.30	3.33	0.47	5.21
		chaff	163	0.56	0.91	0.10	0.16	0.74	1.20
		sticks	148	0.76	1.12	0.12	0.18	1.06	1.57
	2497	stalks	2497	0.57	14.23	0.08	2.00	1.75	43.70
Cowpea	305	beans	247	3.64	8.98	0.30	0.74	1.36	3.36
		pods	58	1.45	0.84	0.10	0.06	2.06	1.20
	591.7	straw	592	1.67	9.88	0.13	0.77	1.88	11.12
Pasture grasses		10701.5	1259	0.45	48.16	0.11	11.77	0.87	93.10
Shrubwood		2956.5	203	0.26	7.69	0.04	1.18	0.27	7.98
Total outputs			14023		203.00		32.42		290.01
Balance (kg)					27.49		9.27		101.78
Balance (kg/ha)					1.88		0.63		6.97

				Land area (ha)	12.3
Farmer:	Bakale	Year	1996	Cultivated area (ha)	10.3
				Fallow area (ha)	2

Input		Amount		Nitrogen		Phosphorus		Potassium	
		kg	kg/ha	%	kg	%	kg	%	kg
Manure		19440	1887.379	1.24	241.06	0.15	29.16	1.00	194.40
Inorganic	20/10/05	0		20	0	4.5	0	4.2	0.00
fertilizer	20/10/10	0		22.2	0	4.4	0	12	0
	27/13/13	0		27	0	4.5	0	10.5	0
Grazing animals		153.6	76.8	0.82	1.26	0.15	0.23	1.51	2.32
Harmattan		9102	740	0.00	0.00	0.09	8.19	2.03	184.77
Fallow land		N:2, P:0.9, K:0.8			4.00		1.80		1.66
Nitrogen fixation		25.75	2.5	100	25.75				
Total inputs					272.07		39.38		383.15

Harvest	Yield	Part		Nitrogen		Phosphorus		Potassium	
	kg dm			%	kg	%	kg	%	kg
Millet	330	grain	218	1.80	3.92	0.30	0.65	0.44	0.96
		chaff	66	1.09	0.72	0.17	0.11	0.73	0.48
		sticks	23	1.19	0.27	0.20	0.05	1.49	0.34
	555.5	stalks	556	0.87	4.83	0.08	0.44	2.29	12.72
Sorghum	2971	grain	2228	1.79	39.89	0.30	6.68	0.47	10.47
		chaff	327	0.56	1.83	0.10	0.33	0.74	2.42
		sticks	297	0.76	2.26	0.12	0.36	1.06	3.15
	6259	stalks	6259	0.57	35.68	0.08	5.01	1.75	109.53
Cowpea	515	beans	417	3.64	15.17	0.30	1.25	1.36	5.67
		pods	98	1.45	1.43	0.10	0.10	2.06	2.03
	999.1	straw	999	1.67	16.68	0.13	1.30	1.88	18.78
Pasture grasses		2518	1259	0.45	11.33	0.11	2.77	0.87	21.91
Shrubwood		2490.75	203	0.26	6.48	0.04	1.00	0.27	6.73
Total outputs			12949		140.48		20.04		195.19
Balance (kg)					131.58		19.34		187.96
Balance (kg/ha)					10.70		1.57		15.28

Farmer:	Lomiyo		Year	1996			Land area (ha)		9
							Cultivated area (ha)		4.7
							Fallow area (ha)		4.3
Input		Amount		Nitrogen		Phosphorus		Potassium	
		kg	kg/ha	%	kg	%	kg	%	kg
Manure		0		1.24	0	0.15	0	1.00	0
Inorganic	20/10/05	50	10.6383	20	10	4.5	2.25	4.2	2.10
fertilizer	20/10/10	0		22.2	0	4.4	0	12	0
	27/13/13	0		27	0	4.5	0	10.5	0
Grazing animals		330.24	76.8	0.82	2.71	0.15	0.50	1.51	4.99
Harmattan		6660	740	0.00	0.00	0.09	5.99	2.03	135.20
Fallow land		N:2, P:0.9, K:0.8			8.60		3.87		3.57
Nitrogen fixation		11.75	2.5	100	11.75				
Total inputs					33.06		12.61		145.85
Harvest	Yield	Part		Nitrogen		Phosphorus		Potassium	
	kg dm			%	kg	%	kg	%	kg
Millet	1251	grain	826	1.80	14.86	0.30	2.48	0.44	3.63
		chaff	250	1.09	2.73	0.17	0.43	0.73	1.83
		sticks	88	1.19	1.04	0.20	0.18	1.49	1.30
	2424	stalks	2424	0.87	21.09	0.08	1.94	2.29	55.51
Sorghum	620	grain	465	1.79	8.32	0.30	1.40	0.47	2.19
		chaff	68	0.56	0.38	0.10	0.07	0.74	0.50
		sticks	62	0.76	0.47	0.12	0.07	1.06	0.66
	2244	stalks	2244	0.57	12.79	0.08	1.80	1.75	39.27
Cowpea	235	beans	190	3.64	6.92	0.30	0.57	1.36	2.59
		pods	45	1.45	0.65	0.10	0.04	2.06	0.92
	455.9	straw	456	1.67	7.61	0.13	0.59	1.88	8.57
Pasture grasses		5413.7	1259	0.45	24.36	0.11	5.96	0.87	47.10
Shrubwood		1822.5	203	0.26	4.74	0.04	0.73	0.27	4.92
Total outputs			8579		105.97		16.24		168.99
Balance (kg)					-72.91		-3.63		-23.14
Balance (kg/ha)					-8.10		-0.40		-2.57

								Land area (ha)	5.7
Farmer:	Dambage		Year	1996				Cultivated area (ha)	4.3
								Fallow area (ha)	1.4
Input		Amount		Nitrogen		Phosphorus		Potassium	
		kg	kg/ha	%	kg	%	kg	%	kg
Manure		12555	2919.77	1.24	155.68	0.15	18.83	1.00	125.55
Inorganic	20/10/05	50	11.63	20	10	4.5	2.25	4.2	2.10
fertilizer	20/10/10	0		22.2	0	4.4	0	12	0
	27/13/13	0		27	0	4.5	0	10.5	0
Grazing animals		107.52	76.8	0.82	0.88	0.15	0.16	1.51	1.62
Harmattan		4218	740	0.00	0.00	0.09	3.80	2.03	85.63
Fallow land		N:2, P:0.9, K:0.8			2.80		1.26		1.16
Nitrogen fixation		10.75	2.5	100	10.75				
Total inputs					180.11		26.30		216.06

Harvest	Yield	Part		Nitrogen		Phosphorus		Potassium	
	kg dm			%	kg	%	kg	%	kg
Millet	2493	grain	1645	1.80	29.62	0.30	4.94	0.44	7.24
		chaff	499	1.09	5.43	0.17	0.85	0.73	3.64
		sticks	175	1.19	2.08	0.20	0.35	1.49	2.60
	1715	stalks	1715	0.87	14.92	0.08	1.37	2.29	39.27
Sorghum	1531	grain	1148	1.79	20.55	0.30	3.44	0.47	5.40
		chaff	168	0.56	0.94	0.10	0.17	0.74	1.25
		sticks	153	0.76	1.16	0.12	0.18	1.06	1.62
	3706	stalks	3706	0.57	21.12	0.08	2.96	1.75	64.86
Cowpea	215	beans	174	3.64	6.33	0.30	0.52	1.36	2.37
		pods	41	1.45	0.60	0.10	0.04	2.06	0.85
	417.1	straw	417	1.67	6.97	0.13	0.54	1.88	7.84
Pasture grasses		1762.6	1259	0.45	7.93	0.11	1.94	0.87	15.33
Shrubwood		1154.25	203	0.26	3.00	0.04	0.46	0.27	3.12
Total outputs			11303		120.66		17.77		155.38
Balance (kg)					59.46		8.53		60.68
Balance (kg/ha)					10.43		1.50		10.65

Farmer:	Kyari		Year	1996				Land area (ha)	16.7
								Cultivated area (ha)	3.18
								Fallow area (ha)	13.52
Input		Amount		Nitrogen		Phosphorus		Potassium	
		kg	kg/ha	%	kg	%	kg	%	kg
Manure		0		1.24	0	0.15	0	1.00	0
Inorganic	20/10/05	0		20	0	4.5	0	4.2	0.00
fertilizer	0/15/0	50	15.72	0	0	8.25	4.125	0	0
	27/13/13	0		27	0	4.5	0	10.5	0
Grazing animals		1038.336	76.8	0.82	8.51	0.15	1.56	1.51	15.68
Harmattan		12358	740	0.00	0.00	0.09	11.12	2.03	250.87
Fallow land		N:2, P:0.9, K:0.8			27.04		12.17		11.22
Nitrogen fixation		7.95	2.5	100	7.95				
Total inputs					43.50		28.97		277.77
Harvest	Yield	Part		Nitrogen		Phosphorus		Potassium	
	kg dm			%	kg	%	kg	%	kg
Millet	2893	grain	1909	1.80	34.37	0.30	5.73	0.44	8.40
		chaff	579	1.09	6.31	0.17	0.98	0.73	4.22
		sticks	203	1.19	2.41	0.20	0.41	1.49	3.02
	1871	stalks	1871	0.87	16.28	0.08	1.50	2.29	42.85
Sorghum	1294	grain	971	1.79	17.37	0.30	2.91	0.47	4.56
		chaff	142	0.56	0.80	0.10	0.14	0.74	1.05
		sticks	129	0.76	0.98	0.12	0.16	1.06	1.37
	2914	stalks	2914	0.57	16.61	0.08	2.33	1.75	51.00
Cowpea	159	beans	129	3.64	4.68	0.30	0.39	1.36	1.75
		pods	30	1.45	0.44	0.10	0.03	2.06	0.63
	308.46	straw	308	1.67	5.15	0.13	0.40	1.88	5.80
Pasture grasses		17021.68	1259	0.45	76.60	0.11	18.72	0.87	148.09
Shrubwood		3381.75	203	0.26	8.79	0.04	1.35	0.27	9.13
Total outputs			10647		190.79		35.05		281.86
Balance (kg)					-147.28		-6.08		-4.10
Balance (kg/ha)					-8.82		-0.36		-0.25

							Land area (ha)		16.44
Farmer:	Adamu		Year	1996			Cultivated area (ha)		14.49
							Fallow area (ha)		1.95
Input		Amount		Nitrogen		Phosphorus		Potassium	
		kg	kg/ha	%	kg	%	kg	%	kg
Manure		3578	246.93	1.24	44.37	0.15	5.37	1.00	35.78
Inorganic	20/10/05	0		20	0	4.5	0	4.2	0.00
fertilizer	20/10/10	0		22.2	0	4.4	0	12	0
	27/13/13	0		27	0	4.5	0	10.5	0
Grazing animals		149.76	76.8	0.82	1.23	0.15	0.22	1.51	2.26
Harmattan		12165.6	740	0.00	0.00	0.09	10.95	2.03	246.96
Fallow land		N:2, P:0.9, K:0.8			3.90		1.76		1.62
Nitrogen fixation		36.225	2.5	100	36.225				
Total inputs					85.72		18.30		286.62
Harvest	Yield	Part		Nitrogen		Phosphorus		Potassium	
	kg dm			%	kg	%	kg	%	kg
Millet	3525	grain	2327	1.80	41.88	0.30	6.98	0.44	10.24
		chaff	705	1.09	7.68	0.17	1.20	0.73	5.15
		sticks	247	1.19	2.94	0.20	0.49	1.49	3.68
	1360	stalks	1360	0.87	11.83	0.08	1.09	2.29	31.14
Sorghum	4639	grain	3479	1.79	62.28	0.30	10.44	0.47	16.35
		chaff	510	0.56	2.86	0.10	0.51	0.74	3.78
		sticks	464	0.76	3.53	0.12	0.56	1.06	4.92
	3315	stalks	3315	0.57	18.90	0.08	2.65	1.75	58.01
Cowpea	724.5	beans	586	3.64	21.33	0.30	1.76	1.36	7.97
		pods	138	1.45	2.01	0.10	0.14	2.06	2.85
	1405.53	straw	1406	1.67	23.47	0.13	1.83	1.88	26.42
Pasture grasses		2455.05	1259	0.45	11.05	0.11	2.70	0.87	21.36
Shrubwood		3329.1	203	0.26	8.66	0.04	1.33	0.27	8.99
Total outputs			15998		218.40		31.67		200.86
Balance (kg)					-132.68		-13.38		85.77
Balance (kg/ha)					-8.07		-0.81		5.22