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*Identification of niches for grain legume technologies*

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## Abstract

Farm characterisations based on constructed farmer typology were conducted in the southern and northern Guinea savannah zones of Nigeria. The research was carried out within the framework of the N2Africa project. N2Africa is a research for development project working in 13 sub-Saharan African countries aiming to improve benefits from cultivating grain legumes through better yielding varieties and enhanced biological nitrogen fixation. Data collection took place in the northern Guinea (Bunkure) and in the southern Guinea (Kachia) savannah zones. The study aimed to understand the role of three grain legumes: cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*) and soybean (*Glycine max*) in the farming systems of the chosen agro-ecological zones and how these legumes can further contribute to improved soil fertility and crop production. Socio-economic data was collected including farm and household sizes, farming objectives of smallholders, livestock, off-farm income or remittances, and labour arrangements. Rainfall data, soil and crop sampling, and biological nitrogen fixation measurements were taken. Major socio-economic differences between the study sites were household sizes, farm size, and livestock densities. The above were all higher in Bunkure than in Kachia. Average annual rainfall ranged between 1392-1797mm in Kachia accompanied by a 195 days growing period. On the contrary, annual rainfall in Bunkure was between 714-841mm per annum with a 135 days growing period. Cropping in Bunkure entails intercropping of cereal and grain legumes. Cowpea is important for food and groundnut is sold for income. Farming in Kachia is oriented towards income generation with ginger being the most important cash crop. Groundnut and soybean are also grown for sale on the market. Maize is the dominant food crop. Analysed soil samples revealed low fertility of soils in Bunkure, well below critical levels of P and K. Low clay content of 11% on average translated into low availability of the important plant nutrients N, P, and K. Average pH on the other hand very satisfactory (6.2), also for Kachia (5.6). Higher clay content of soils (24%) in Kachia showed higher soil fertility in terms of organic carbon, total N, available P, and exchangeable cations. Average plant N derived from biological nitrogen fixation in grain legumes was 74% (84 kg N $ha^{-1}$) in Bunkure for cowpea and groundnut. In Kachia, this was 44% (44 kg N $ha^{-1}$) for groundnut and soybean. Large variations in nitrogen fixation occurred between fields but cowpea gained the highest benefits from nitrogen fixation in Bunkure, whilst groundnut gained the least N from biological fixation in Kachia. This study was able to show that grain legumes occupy an important role within farming systems in northern Nigeria mainly through their contribution to food self-sufficiency, farm income, and fodder for livestock. The use of legume fodder to feed livestock in the southern Guinea zone is however much less than in the north and most farmers left their residue on the field after harvest. Other cash crops mainly ginger compete with grain legumes for crop land but soybean and groundnut are still important for income generation in the southern Guinea zone. At both study sites, grain legumes were the most profitable crops on a per hectare basis. The study concluded that, additional benefits from grain legumes in northern Nigeria should come through better management of residue to maintain soil fertility in Kachia where farmers have less need for fodder. At Bunkure, improved handling and storage strategies for farmyard manure are necessary to ensure good quality in nutrient cycling through legume residue that is fed to livestock.

**Keywords:** farm characterisation, farmer typology, grain legumes, cereal-legume intercrop, crop-livestock integration, farming system, cropping system, savannah agro-ecology.

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## 1. Introduction

Grain legumes such as cowpea, groundnut, and soybean are important crops in the sub-humid to semi-arid savannah agro-ecologies of northern Nigeria. These crops provide a wealthy source of proteins and contribute to household food self-sufficiency as well as provide income generation opportunities for smallholders that grow these crops. Recent FAO data (FAOSTAT/FAO. 2010; Akibode and Mareda 2011) shows that, Nigeria is the world's number one producer of cowpea (*Vigna unguiculata* L Walp) with a total annual production of 1.1 million tons between 2006 and 2008. Total land coverage of cowpea in Nigeria is estimated by the FAO to reach 5 million hectares. With these figures the country has maintained the top spot in global cowpea production alongside other west African countries for the past decade and more.
Cowpea production occurs in the sub-humid to semi-arid agro-ecological zones (AEZ) of northern Nigeria where cropping is centred on cereal and legumes systems (Ajeigbe, Singh et al. 2010). Average yields for cowpea reported for northern Nigeria stand at a mere 230 kg $ha^{-1}$ whereas other regions report yields up to tenfold (i.e. 2.3 tons $ha^{-1}$).
Apart from cowpea, northern Nigeria is also renowned for the cultivation of groundnuts (*Arachis hypogaea*) and soybean (*Glycine max*). Groundnut and soybean have been promoted as income generating crops for smallholder farmers in the same agro-ecological zones of northern Nigeria. Research, promotion and dissemination of improved varieties and accompanying technologies continues to contribute to increased legume production in northern Nigeria (IITA 2008). Two major research institutions involved in cropping systems of northern Nigeria are the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Institute of Tropical Agriculture (IITA) .
Livestock, is an important part of farming systems in this region (Smith, Naazie et al. 1997). Crop and livestock are integrated at farm level and has potential for reciprocal benefits, i.e. crop residue as fodder for livestock and animal manure serving as major nutrient replenishment in crop production.

While most of the literature on soil fertility in sub-Saharan Africa project a scenario of continuous nutrient depletion and severely negative nutrient balances (Sanchez 2002; Cobo, Dercon et al. 2010), specific research in semi-arid zones of northern Nigeria show conscious soil fertility management strategies by smallholders that combine organic and inorganic inputs to sustain agricultural production (Harris 1998; Hoffmann, Gerling et al. 2001). Hoffman et al (2001) found annual inputs of 87, 33, and 120 kg $ha^{-1}$ for N, P, and K respectively in northern Nigeria which are well above the input figures given for other regions on the continent especially towards the eastern and southern parts. Partial nutrient balances given in the literature also reveal stark contrasts between northern Nigeria and eastern Africa for example.

The N2Africa project is a research and development initiative working mainly with grain legumes in farming systems of smallholders in sub-Saharan Africa. It aims to raise productivity of legume crops, increase average levels of biological nitrogen fixation (BNF) and income for farmers gained through the cultivation of legumes. To achieve this, N2Africa adopts an R4D approach in designing *best-fit* technologies of grain legumes for food, income, and fodder.
This report is based on a study conducted in northern Nigeria within the framework of N2Africa. It aims to evaluate the farming systems of cereal-legume and livestock farmers in two agro-ecological zones of northern Nigeria in order to propose *best-fit* technologies through which farmers are able to capture the potential of nitrogen fixation from atmospheric reserves towards good management of soil fertility for sustained crop production. This research explores socio-economic as much as biophysical aspects of farming systems at the selected study sites. It refrains from a purely comparative analysis but rather on

the uniqueness of both agro-ecological zones in achieving these goals within their respective socio-ecological domains (Ojiem, de Ridder et al. 2006).

In order to achieve the above set objectives, 5 hypotheses have been developed as follows:

1. Adopting best-fit legume technologies in cropping systems will contribute to improved soil fertility through biological $N_2$-fixation and thereby increasing productivity of agricultural fields. Legume crop residue provides high quality fodder to feed livestock.

2. Precipitation and length of the growing period are major biophysical factors determining the type of legume technologies suitable to an agro-ecological zone. These factors determine not only the type of grain legumes but also the specific varieties that can be cultivated in the given zone.

3. Adoption of legumes is strongly influenced by the socio-economic factors enabling and/or constraining farmers. These factors such as household food self-sufficiency and labour availability constrain/enable the production of grain legumes to a certain extent based on level of farmers' resource endowments.

4. Farmers with integrated crop-livestock systems are practising or willing to adopt legume technologies such as groundnut or dual purpose cowpea and soybean varieties on their farm. These dual purpose legumes will provide high value fodder for animals as well as grain. Manure from livestock can also serve as valuable fertiliser as input on the farm.

5. Adopting legume technologies depends on preferences of farmers and the choice of legumes depends on farmers' production objectives, i.e. food self-sufficiency and livestock demand for fodder are the major influencing factors for the adoption of different legume varieties.

## 2. Materials and methods

This research applied the aggregated data collection methods from the AfricaNUANCES framework of Plant Production Systems group (PPS) of Wageningen University. NUANCES stands for Nutrient Use in Animal and Cropping systems – Efficiency and Scales (van der Burg, Tittonell et al. 2006). Methods of data collection described within NUANCES are applied within the framework of the N2Africa project. Data collection on which this report is based takes place in two agro-ecological zones (AEZ) in northern Nigeria: the southern Guinea and the northern Guinea savannah zones.

### 2.1 Farm typology creation

Participating farmers in this study were selected from the N2Africa Nigeria baseline survey (Franke and de Wolf 2011). In the baseline survey, approximately 100 farmers per local government areas (LGA) were randomly selected from communities within the LGA and interviewed. All ten action sites of the N2Africa project in Nigeria were involved in the survey. Within the survey, farmers were interviewed on their socio-economic status, components of farming systems, their farming resources and involvement in off-farm income among other issues. The results of this survey were used in selecting the participants for this study as well as establishing heterogeneity between farmers and identifying the various farm types. Two of the ten LGAs were selected for this study each representing an agro-ecological zone each, i.e. Bunkure in the northern Guinea and Kachia in the southern Guinea savannah zone. After establishing the various farm types, five farmers per type were selected for the detailed farm characterisations. These farmers were pre-selected by the researcher and traced back to their respective communities with the assistance of an agricultural extension agent from the LGA. In cases where the pre-selected farmers could not be identified, they were replaced from the list containing all farmers.

Farm typologies assists in understanding farmer heterogeneity due to differences in resource endowment of farmers (Tittonell, Vanlauwe et al. 2005). Identification of farm types in this study is based on production resources, input use, land sizes, source of drinking water, livestock numbers, reliance on off-farm income and/or remittances. The above data were all available from the baseline survey however, brief interviews were conducted at the beginning of the study through which additional data was collected such as the homestead GPS Waypoint of farmers. Preliminary interviews were done so as to verify data through which the farm typologies could be created. Three farm types were identified. Major differences that influenced the creation of types were total crop land, number of livestock, farm income, and remittances.

### 2.2 Study sites and background information

The study sites in northern Nigeria represent two agro-ecological zones namely, the sub-humid southern Guinea savannah and the northern Guinea savannah characterised as semi-arid. Bunkure local government lies in the northern Guinea savannah, whilst Kachia lies in the more southern Guinea savannah zone. These two agro-ecologies were purposefully chosen to express possible agro-ecological differences in farming systems. Bunkure was chosen to represent relatively intensive cropping systems in a densely populated region typical of some areas in the northern Guinea savannah (Harris and Yusuf 2001). The selection of Kachia in the southern Guinea savannah is to show possible socio-economic and cultural differences influencing cropping systems as compared to Bunkure. Secondly, the increased diversity of crops in cropping systems of the southern Guinea zone could have a possible influence on the cultivation of grain legumes and if so, this could be highlighted in the cropping systems of Kachia.

Table 1. A summary of rainfall and biophysical information at both research locations, Bunkure and Kachia local governments.

| | *Bunkure* | | *Kachia* | |
|---|---|---|---|---|
| Annual rainfall (mm) | 714-841 | | 1392-1797 | |
| Dominant soil type | Alfisols (Luvisols) | | Alfisols (Luvisols) | |
| Length of growing period (days) | 135 | | 195 | |
| Major crops and yields (kg $ha^{-1}$) | Maize | 850 | Maize | 850 |
| | Millet | 650 | Millet | 650 |
| | Rice | NA[1] | Soybean | 1050 |
| | Sorghum | 750 | Sorghum | 750 |
| | | | Ginger | 3300 |
| Legume crops and yields (kg $ha^{-1}$) | Cowpea | 675 | Cowpea | 675 |
| | Groundnut | 1000 | Groundnut | 1000 |

[1]Data not available.

Source: (Ogungbile 1999; Abaje, Ishaya et al. 2010; Franke, Rufino et al. 2011).

Data collection took place in the villages of Gweneri in Bunkure local government and Gumel in Kachia local government. Throughout this report, data is presented per local government rather than on village basis. Throughout the five month fieldwork phase, the researcher was based at the Kano research station of the International Institute of Tropical Agriculture (IITA). All data collection activities were carried out from this point. For data collection in Bunkure local government, daily trips were made to the study site for interviews, sampling and field monitoring. Farmers from Dususu community which is also within Bunkure local government, were involved in socio-economic surveys of this study used for the construction of farm typologies. Accessibility of this village community during the rainy season is however difficult, hence the farmers from Dususu were excluded from biophysical data sampling and field monitoring. Trips from Kano were made to Kachia local government for socio-economic surveys and biophysical data collection. Two major trips were made to this study site first for socio-economic surveys, soil sampling and sampling for measuring biological nitrogen fixation. The second trip was for crop sampling to determine yields, crop, and farm productivity. In total, the researcher spent one month collecting data in Kachia local government.

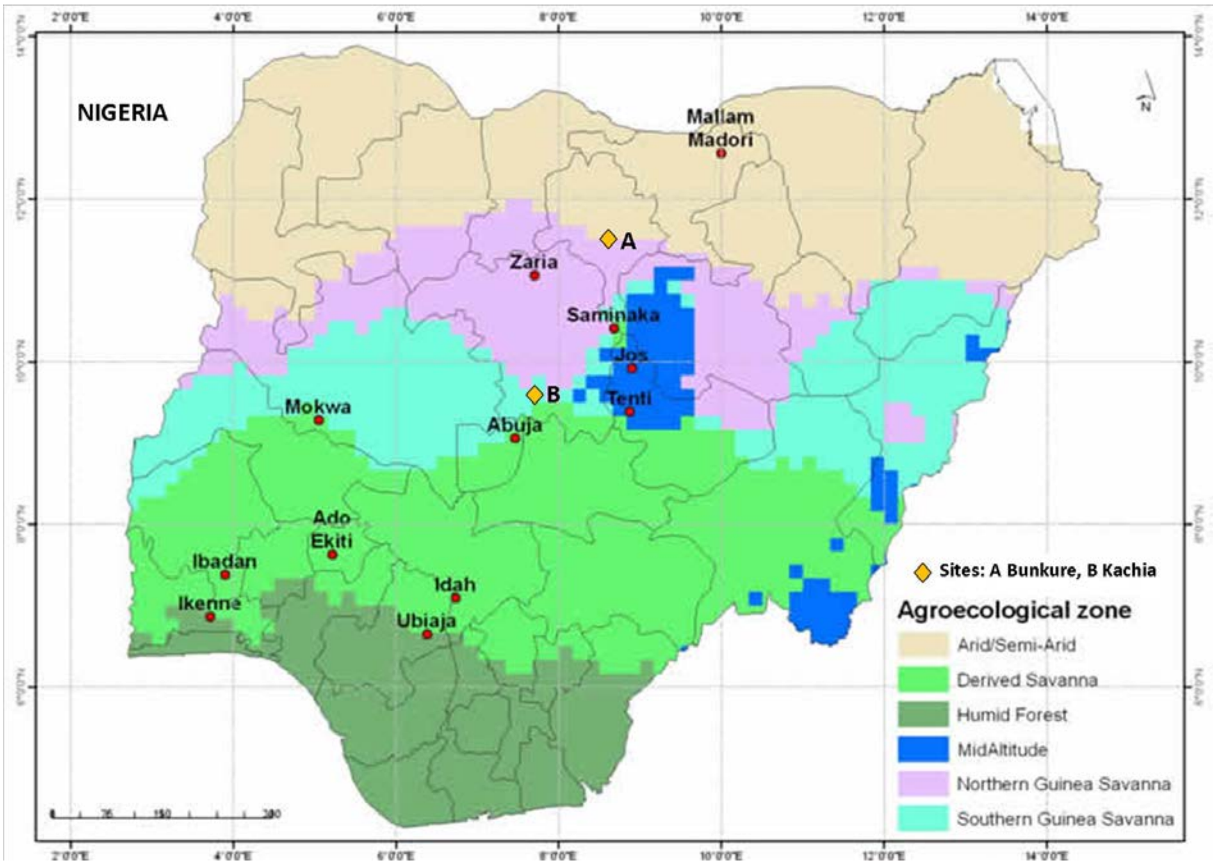


*Fig 1. Agro-ecological sub division of Nigeria with the study sites of Bunkure (A) and Kachia (B).*

### 2.3 Socio-economic data collection

Socio-economic data collection was on household dynamics, farming orientation and off-farm income/employment, cropping systems, use of improved crop varieties, use of organic and inorganic inputs, farmer estimation of yields, major constraints to crop production and livestock husbandry. These data were collected using structured interviews following van der Burg *et al*. (2006).

Socio-economic surveys were conducted with assistance from agricultural extension agents (EA) from local agricultural and rural development partners also involved in the N2Africa project. EAs recruited for each study site came from the respective local government and hence had ample experience and recognition among the farmers of that village.

*Food self sufficiency*

The role of legumes in food self-sufficiency of households is analysed by looking at total food production per farm and comparing that to total food requirements of the household. On average, a household member needs 2100 Kcal day$^{-1}$ and 59 g day$^{-1}$ of proteins (FAO 1997). Since cereals are prioritised for food, food self-sufficiency was first determined with total cereal production. In case of a deficit legumes were then considered as the next food crop that would be consumed. It is assumed that cowpea would be consumed first before groundnut. Soybean would not be consumed by the household.

Sale of produce is hence the surplus of what is not consumed domestically. Ginger production by households in Kachia was ignored in this part but added to household sale of produce. The energy and protein content of food crops used in the calculations are presented in the Appendices (Section 7.1).

*Income generation*
Amount of crop produce sold is the surplus from food consumed at the household from total food production per farm. The food crops considered are the major cereals maize, sorghum and millet, cowpea, and groundnuts. All soybean is sold and so is ginger in Kachia. Surplus fodder in Bunkure is also sold. Prices of grain and fodder were prevalent market prices at the time of the fieldwork between August and November 2011. These are prices at which farmers sell their produce when brought to the market and sold to wholesalers or local traders. Costs of inputs and labour per day were also taken during the time of fieldwork. A detailed table of prices and costs of inputs is produced in the Appendices (Section 7.1).

**2.4 Biophysical data**

Biophysical data collection for this study included rainfall data, soil sampling, and crop sampling. Rainfall data were retrieved from weather stations of the state agricultural and rural development organisations local governments. Soil sampling as well as sampling for yield determination follows data collection guidelines of van der Burg *et al.* (2011). Biophysical data collection commenced after completion of socio-economic interviews with farmers. Farmers were notified on the kind of information that the research wanted to acquire through biophysical measurements. Farmers were instructed to show 2 – 4 of their fields, one field close to their settlement, one at the outskirts of the community and one further away.

*Soil sampling*
Soil samples were collected per field of every farmer surveyed in this studied. On average, 3 fields per farmer were sampled. Soil sampling was spread across close, intermediate, and distant fields so as to capture soil fertility and management gradients between different field types. In Bunkure, due to a higher number of fields per farm, it was relatively easy to samples 3 fields per farmer. In Kachia an average of 2 fields per farmer were sampled. Distant fields (> 2km from homestead) that were not accessible by motorable road were not sampled. Composite soil samples were collected at a depth of 0-20cm in a W pattern across the entire field. 12-15 samples collected per field and mixed to form one composite sample. About 500g of composite soil samples were collected per field and prepared for analysis.
Soil samples were air dried and passed through a <2mm sieve to remove plant and animal debris. Approximately 200g of prepared soil sampled were sent for physico-chemical analysis at the IITA analytical laboratory (IITA 2011) in Ibadan, Oyo State of Nigeria. Soils were analysed for pH (in a 1:2 soil water volume ratio), organic carbon and total N were analysed using dry combustion method, available P through Olsen method. Exchangeable cations (K, Mg, Na, and Ca) were determined using ammonium acetate extraction. Particle sizes (sand, silt, and clay) were obtained using the hydrometer method.

*Plant sampling*
Plant sampling was done on the same fields from which soils were sampled. Samples for measuring nitrogen fixation were taken first at mid podding stage between the months of September and October (middle point of the rainy season) depending on time of planting. Further sampling to determine yield of legumes were done on same fields as BNF samples were taken. For cowpea, sampling for yield was done in end of September to mid-October whilst for groundnut and soybean, this was at the end of the rains in November. Sampling of cereals was done also at the end towards the rainy season in November simultaneously with groundnut and soybean. Fields with cereals were chosen based on availability among participating farmers. As many fields were sampled as available since some farmers had already harvested their cereal crops.

Plant samples were taken at physiological maturity to determine yields. Plants were sampled at 3-4 randomly selected locations on the field. Harvested area was measured from where plants were sampled. A total area of 5.7 $m^2$ (2.1 x 2.7 m) was harvested for yield assessments per fields. Aboveground biomass in fresh weight (FW)was taken. Sub-samples were taken and oven dried to constant weights (DW). Duration of oven drying ranged between 48-72 hours at about 70°C. Biomass was separated into grain and stover and extrapolated to achieve yield in kg $ha^{-1}$.

Crop sampling for BNF measurements was carried out at mid podding stage for all three legumes. Type of legume crop sampled depended on farmers' choice for legumes and the fields that were accessible during field work. Main crop harvested for BNF analysis in Bunkure was cowpea and groundnuts, in Kachia this was groundnut and soybean.

*GPS Waypoint data*

Waypoints (coordinates) were collected for all monitored farmers by use of a Garmin etrex Legend HCx device. Waypoints were collected for homesteads and fields of farmers. Homestead waypoints were a single coordinate taken at the homestead. Field waypoints were taken at all corners of fields during preliminary transect walks on fields. Fields smaller than 20 m x 20 m were measured using a surveyors tape measure.

Waypoint data were used to calculate field sizes of farmers, distances from the homestead to fields as well as distance from central point in the village to a major market. Garmin Map Source software was initially used to access and view collected waypoints. MapInfo Professional v10 software was used to analyse waypoint data in determining field sizes and distances.

*Field distances*

Field classification in Kachia were as follows: home/close fields were 25-100 m from homestead, intermediate fields were between 140-300 m from the homestead and distant fields were 750 m up till about 2300 m. The field distances were absolute measurements by GPS device. Actual distances travelled on foot, bicycle or motorbike by farmers reached over 3000 m in Kachia for some distant fields. Field classification for Bunkure was as follows: close/home fields were between 25-200 m from homestead, intermediate fields 200-600 m from homestead and distant fields were 600 m and further from the homestead. The most distant field in Bunkure was 1700 m from the homestead.

*Nutrient budgets*

Nutrient balances of N, P and K were calculated for the three farm types for both study sites. Field level balances were initially carried out separating cereals and legumes before being aggregated to farm level. A number of assumptions were made in order to calculate the nutrient balances. Loss of nutrients through erosion, volatilisation, and leaching were neglected in the calculations. Nutrient input from organic and inorganic sources were established from this study. Further nutrient inputs were considered, for example deposition of P and K from seasonal harmattan dust in northern Nigeria was establish at 0.7 kg P and 17 kg K $ha^{-1}$ $year^{-1}$ from the literature (McTainsh 1984; Stoorvogel, Van Breemen et al. 1997). Input of N through atmospheric deposition (10 kg N $ha^{-1}$ $year^{-1}$) was taking into the calculations (Wortmann and Kaizzi 1998). N contribution from biological $N_2$ fixation during legume cultivation is taken from own data presented in this report.

Outflow of nutrients from the farm was defined as the harvest of both economical crop parts and residue. Crop harvest and removal of residue was considered a loss from the farm. Nutrient content of crop parts is taken from Harris (1998) and Wortmann and Kaizzi (1998). These parameters are given in the Appendices (Section 7.1)

### 2.5 Biological nitrogen fixation: sampling and analysis

Biological nitrogen fixation was investigated using the $^{15}N$ natural abundance method (Unkovich, Herridge et al. 2008). Legume sampling was done at mid podding stage, above ground biomass was harvested and fresh weight (FW) taken. Reference samples were taken as close to legumes samples as possible and at same physiological maturity.

Reference plant species were broad leafed non leguminous weeds growing in the same fields as the legume sampled. The most frequent weed species taken was *Chromolaena odorata*. At other instances, a 'weed mix' was sampled. BNF samples were oven dried and roughly ground on IITA Kano premises. BNF samples were sent to CIAT-TSBF in Nairobi for further grinding. $^{15}N$ analyses were conducted at the analytical laboratory of KU Leuven in Belgium.

Calculating percentage N from natural abundance (%Ndfa) was done using the equations from Peoples *et al* (1989) and Unkovich *et al* (2008).

Atom ‰ $^{15}N$ was converted to $\delta^{15}N$ with the equation;

$$\delta\,^{15}N = 1000 * \frac{(\text{atom ‰ } ^{15}N \text{ of sample - constant atom ‰ } ^{15}N)}{\text{constant atom ‰ } ^{15}N} \quad (1)$$

$$\%Ndfa = \frac{(\delta^{15}N \text{ of reference plant - } \delta\,^{15}N \text{ of } N_2 \text{ of fixing legume})}{\delta^{15}N \text{ of reference plant} - B} \times 100 \quad (2)$$

Where, $\delta^{15}N$ of reference plant is the $^{15}N$ of the sampled reference plant,

$\delta\,^{15}N$ of $N_2$ of fixing legume is $^{15}N$ of sampled $N_2$ fixing legume crop

constant atom ‰ $^{15}N$ = 0.3663 (Peoples, Faizah et al. 1989)

B is the adjusted value for isotopic fractioning of $^{15}N$ within shoot and roots of plant.

Determination and use of a B value is important since only aboveground biomass is used to determine %Ndfa. From Unkovich et al (2008), B value is not significantly influenced by varietal variation between similar legume species but rather the type of rhizobium species that nodulates with legumes. None of the fields sampled were inoculated with rhizobia by farmers.

Table 2. 'B' values for cowpea, groundnut and soybean crops obtained from Unkovich *et al* 2008.

| Legume species | 'B' value |
|---|---|
| *Vigna unguiculata* | -1.61 |
| *Arachis hypogaea* | -1.95 |
| *Glycine max* | -2 |

'B' values established for respective legumes in greenhouse and field experiments (Unkovich, Herridge et al. 2008).

### 2.6 Statistical data analysis

SPSS 19 statistical package was used to establish variations in soil fertility and biological nitrogen fixation. The different farm types, field distances categories, and study sites were taken as the independent variables. Analysis of variance (ANOVA) at 5% ($\alpha = 0.05$) significance level was used.

## 3. Results

### 3.1 Farm typologies and characterisation of the study sites

*General differences between studied sites*

From Table 3, variations can be seen between study sites for cultivated area and number of fields managed per household. Livestock densities especially cattle are lower for Kachia local government than in Bunkure. Less than 10% of the farmers in Kachia own a cow. Farmers irregularly keep cattle if there is enough income from the previous cropping season to purchase a cow and feed. This kind of livestock husbandry entails fattening 1-2 cows and selling them at the end of the cropping season. At the time of data collection, one farmer in Kachia owned cattle. Eighty per cent of farmers in Bunkure owned at least one cow. Sixty per cent of those farmers have an average of 24 cattle. Herds of smaller ruminants as sheep and goats are larger in Bunkure than in Kachia. Pigs are solely kept in Kachia.

Household sizes are twice as large in Bunkure as in Kachia. This is mainly because extended families live under one household in Bunkure. For example, the married male children of the farmer, the farmer, his spouse and unmarried children live in the same compound. They cultivate the same fields and their food comes from the same harvests. This was however not the case in Kachia. Although some extended families live in the same compound, most farmers live only with their immediate families. This differentiated the household sizes between study sites considerably.

The percentage of farmers involved in off-farm income activities in Kachia is more than in Bunkure. More households receive remittances from members living outside the community in Bunkure than in Kachia. Export of household labour off the farm is more in Kachia than in Bunkure local government.

Table 3. Summary of major socio-economic indicators for the 2 local government areas studied. Data are averaged for all studied households (HH) for both research locations. Data is based on final sample of participating farmers in Bunkure (21) and Kachia (18).

| Indicator | *Bunkure* (n=21) | *Kachia* (n=18) |
|---|---|---|
| Total crop land[1] (ha) | 4.7 | 1.1 |
| No. of fields[2] | 7 | 2 |
| Average field size[1] (ha) | 0.66 | 0.53 |
| Average distance to fields[1] (m) | 415 | 802 |
| Cattle density/HH[2] | 10 | 1 |
| Smaller livestock/HH[2,3] | 48 | 12 |
| | | |
| HH size[1] | 29 | 13 |
| % HH renting farmland[1] | 5 | 6 |
| % of HH cultivating legumes[1] | 76 | 75 |
| % of farmland under legumes[4] | 36 | 28 |
| | | |
| % involved in off-farm income[1] | 24 | 72 |
| % HH receiving remittances[2] | 19 | 17 |
| % HH exporting labour off farm[1] | 14 | 22 |

[1]Own data.

[2]Data derived from N2Africa baseline survey conducted in northern Nigeria (2011).

[3]Smaller livestock refers to goats, sheep, and pigs

[4]This concerns cowpea, groundnut, and soybean. In the case of intercropping with cereals, a visual estimation of legume cover over total size of fields was used to attain area cropped to legumes.

*Bunkure Local Government*

Nine per cent of household heads in Bunkure are directly involved in off-farm income generating activities. Off-farm activities include the ownership of a store selling basic groceries or operation of a grain milling machine. Other household members engaged in off-farm income generating activities are sons of the household heads. They are often employed in the local government administration office. This is however only true for wealthier households. Women infrequently export their labour off farm weeding other fields (mainly on rice fields of family relations). This is not regarded as an income generating activity since they are not paid in cash but could collect the weeds as fodder for their goats and sheep.

Wealthier households in Bunkure receive remittances from both distant and close family members living and working in major cities of Nigeria. These remittances serve as an important source of money for investing into farming. Remittances are often used to purchase agricultural inputs. Sources of potable water in communities were either from a river or stream, a community well, or a private well situated within the homestead. Poorer households accessed water either from a nearby stream or river or from the community borehole. Households with medium resource endowments got water from the community borehole or had access to a private one. Wealthier households had access to both community as wells as private households (as the wells were built by them).

Mode of transportation in this local government is either by foot, bicycle or motorbike. Vehicles are solely used for collective transportation of farm produce and other goods to and from the market. Bicycles and motorbikes are used to access remote fields as well for transporting harvested produce to the homestead. Poor households own a bicycle but no motorbike, medium endowed households own an average of 3 bicycles and 1 motorbike. Wealthier households own bicycles and at least 2 motorbikes.

*Kachia Local Government*

Off-farm employment is an important source of income for most (72%) of the households in Kachia. Wealthier households had at least one member having permanent off-farm employment. This is mainly the household head who was a civil servant at the local government administration or in a neighbouring one. In this type of farm households, women and children do the active farming and farm management activities but decision making on land use, cropping and use of harvest was carried out by the male head. In medium resource endowed farm types, at least one member (either the male head or spouse) was engaged in an off-farm income generating activity. Off-farm income activities for this farmer typology are usually a small to medium scale enterprise such as mechanic, blacksmith, or grain miller. Women are usually involved in small businesses and trading of both agricultural and non-agricultural products. Low resource endowed farmers had no permanent off-farm income generation activity. 11% of these farmers had at least one member of the household occasionally employed as casual labour off farm.

Sources of domestic and drinking water were either from a river or stream, a community, or a private well. Wealthier households had access to their own private wells. So did some medium endowed households. Poorer households shared a community borehole or fetched water from a nearby stream or river.

Table 4. Major differences in resource endowment of farm types at both study sites.

| Farm type | n | HH size | Farm size (ha) | No. of fields | Land (ha) per HH member | Cattle | Sheep/ goats | Pigs | Off-farm income | Use of hired labour |
|---|---|---|---|---|---|---|---|---|---|---|
| *Bunkure* | | | | | | | | | | |
| 1 | 6 | 21 | 2.7 | 4 | 0.13 | 3 | 26 | 0 | None | Occasional |
| 2 | 6 | 29 | 4.0 | 6 | 0.14 | 11 | 47 | 0 | Remittances | Throughout season |
| 3 | 9 | 36 | 6.0 | 9 | 0.17 | 17 | 69 | 0 | Remittances | Throughout season |
| *Kachia* | | | | | | | | | | |
| 1 | 5 | 8 | 0.5 | 1 | 0.06 | 0 | 3 | 2 | Casual labour | None |
| 2 | 7 | 12 | 1.0 | 2 | 0.08 | 0 | 7 | 4 | SME[1] | Occasional |
| 3 | 6 | 18 | 1.6 | 3 | 0.09 | 1 | 12 | 7 | Civil servant | Throughout season |

[1]SME = Small to medium scale enterprise.

Table 5. Household (HH) characteristics of the constructed farmer typologies. Typologies based on own and N2Africa socio-economic surveys conducted in 2011.

| Farm type | HH Characteristics | Source of drinking water | Major mode of transport for HH | No. of HH sampled in this typology[1] |
|---|---|---|---|---|
| *Bunkure* | | | | |
| 1 | Mud/brick houses and compound. Primary focus on crop production, 1-3 cows. Inorganic inputs prioritised for cereal production | Communal well, stream/river. | Mainly by foot, 1-2 bicycles per HH | 35 |
| 2 | Mud/brick houses and compound. More cattle but large flock of sheep/goats. | Communal and private well. | 3-5 bicycles per HH. HH head possesses a motorbike. | 35 |
| 3 | Cemented houses and compound. Large livestock herds, and relatively high use of inorganic inputs. Receive remittances from members working in Kano or Abuja. Some HH members working at local government Admin office. | Communal and private well. | 3-5 bicycles per HH. >2 motorbikes in the HH. | 24 |
| *Kachia* | | | | |
| 1 | Small land holdings. Labour exported off farm for additional income. | Communal well, stream, or river. | By foot | 17 |
| 2 | One or more members own a SME[2], blacksmith, mechanic, etc. | Communal and private well | One motorbike | 19 |
| 3 | One or more HH members is a civil servant. Farming as secondary occupation (by wife and children). Often purchase or rent extra land for farming. | Communal and private well | At least one motorbike or a vehicle | 16 |

[1]Number of HH selected from N2Africa baseline data for constructing farm typologies.

[2]SME stands for small to medium scale enterprise.

### 3.2 Farming systems and practises

#### *3.2.1 Bunkure local government*

Cropping is done by men in this community. Women are normally not farmers.

Farms in this local government integrate crop and livestock production. Crops cultivated range from cereals, legumes, cassava, sweet potato, and vegetables. Major cereals include: sorghum (*Sorghum bicolor* L. Moench), millet (*Pennisetum glaucum*), maize (*Zea mays*), and rice (*Oryza sativa*). Cereal crop coverage in this local government is highest for sorghum, millet, rice and maize in that decreasing order. Legumes cultivated are: cowpea (*Vigna unguiculata* L. Walp), groundnuts (*Arachis hypogaea*) and soybean (*Glycine max*). Groundnut had the largest coverage of all observed fields followed by cowpea and soybean in that descending order.

Vegetables as okra (*Abelmoschus esculentus*), peppers (*Capsicum frutenscens*) and tomatoes (*Solanum lycopersicum*) are also cultivated for both domestic consumption as well as for sale.

Sorghum, millet and maize are the major food crops and are cultivated by all farmers. Cowpea is an important component of diets in the area and also widely cultivated in the area (Franke, Rufino et al. 2011). Groundnut and rice are predominantly grown for income generation by all farmers. Soybean is cultivated by few farmers also for income but length of the growing period in this agro-ecological zone is too short to cultivate most of the existing varieties (Franke, Rufino et al. 2011).

Farmers keep cattle, goats and sheep. All farm households keep free-ranging poultry (mainly chickens). Cattle are kept under an extensive system; goat and sheep in a semi-intensive system. In the extensive system of cattle husbandry, cattle are kept and grazed outside the farm. Neither are they corralled at the homestead of the farmer at night. Within the semi-extensive system in which goats and sheep are reared, the animals are grazed in open or communal pastures during the day and corralled at the homestead during the night. During the cropping season, they receive crop residue, grass, and weeds while at the homestead.

*Land tenure*

Land for agricultural production is acquired through inheritance. Purchasing land is rare and was not encountered during fieldwork. Land is solely owned by the male head of the household and he is responsible for distributing both farm land and settlement area to his sons. Male descendants of the households can acquire land for crop production once they are matured and have acquired a spouse. Decisions regarding land use are also taken by the male head of the household. Ninety five per cent of all farmers surveyed acquired land through family inheritance. Five per cent rented part of the land of which they farm.

*Cropping systems*

Bunkure local government has a 135 day growing period (LGP). The rainy season commences in May and ends in October. Land preparation is carried out between the months of March and May. Land preparation is done with oxen drawn implements or manually with a handheld hoe. The major activity is the construction of ridges. Planting commences towards the end May right after the first substantial rains have fallen through to July. By the end of November, all crops have been harvested from the fields.

Traditional cropping systems recorded for this area is the intercropping of cereals with legumes. Cereals are planted first and relayed with legumes toward the end of June. Common combinations are: sorghum-cowpea, sorghum-groundnut, sorghum-millet-cowpea, sorghum-millet-groundnut. Cowpea and groundnut are often planted together in intercrop with cereals. Farmers cultivate all of their fields during the rainy season.

*Traditional versus improved cropping systems*

Intercropping of cereals and legumes is done in *replacement* pattern. This is the type of intercropping whereby single cereal rows were substituted by a single row of either cowpea, groundnut or soybean (Snaydon 1991). In the case where groundnut and cowpea were planted on the same field, they were mixed within the same row. This was the most prevalent trend of cropping observed in the region. Another type of intercropping recorded at this site was the replacement of 2-4 rows (strips) of cereal stands with legumes. This was especially common for sorghum-groundnut intercrops but also for sorghum-cowpea. Farmers and agricultural extension agents referred to this as an ‘improved’ system of cropping (Ajeigbe, Singh et al. 2010). Both planting patterns are illustrated in figure 2.

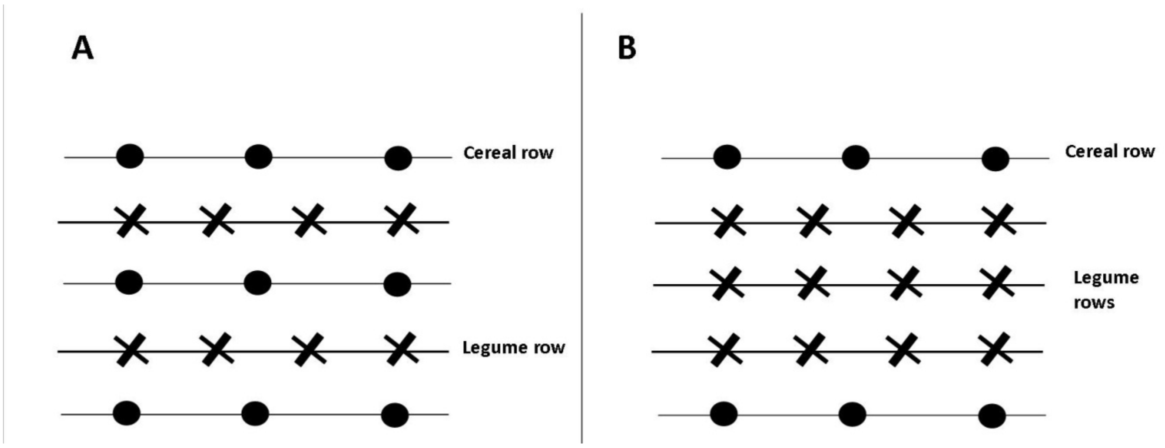


*Figure 2. Illustrations of traditional (A) and improved (B) planting patterns for cereal-legume cropping systems in Bunkure local government. Ridges for cereals as well as legumes are constructed with same dimensions.*

*Cropping calendar*

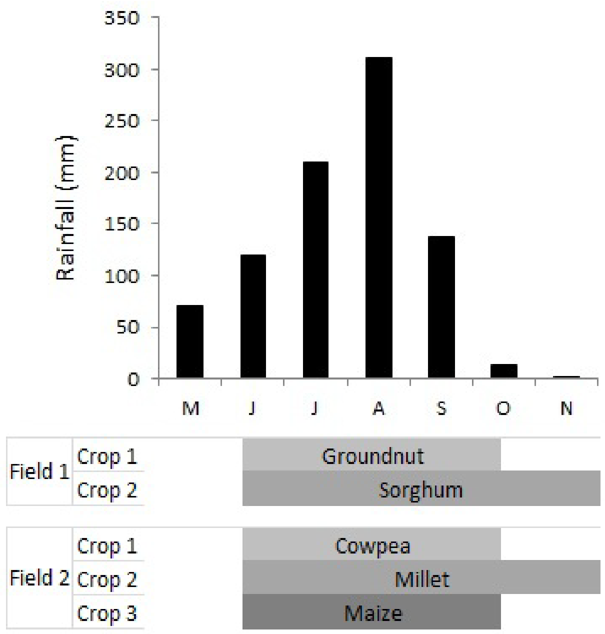


*Figure 3. Seasonal annual cropping calendar of Bunkure local government. Illustration depicts a fictive farm composed of two fields. Fields show a typical intercrop of cereals and legumes at this site.*

*Farm management activities*

Land preparation entails clearing and burning of cereal stubble not grazed by cattle during the dry season. Ploughing is carried out by oxen drawn ploughs. During ploughing, manure deposited on fields throughout the dry season and farmyard manure from the homestead is incorporated into the soil. After ploughing, ridges are constructed with average dimensions of 70-100 cm apart and 25-40 cm high. Weeding is done twice on intercropped fields. This is combined with mending of ridges. This activity is performed manually. Fertilizer application in cereals and legumes is done at planting or 4 weeks after panting. Fertilizer is drilled in at the base of plants and covered with soil. Application of insecticides is done in cowpea cultivation. This is only upon incidence of insect attack. Maize and cowpea are harvested at the end of August through to mid-September. Groundnut, rice and soybean are harvested late in October. Sorghum and millet are the final crops harvested at the end of the cropping season throughout November.

*Livestock*

All farmers keep livestock in Bunkure local government. Integration of livestock at farm level depends on type of livestock. Generally, sheep and goats are kept at the homestead. They are fed with crop residue and crop wastes from the household. During the day, they graze on communal pastures surrounding the village. Their faeces and urine are composted with household waste to produce farmyard manure. Cattle on the other hand are kept predominantly outside the farm. Farmers 'employ' agro-pastoralist Fulani herdsmen to graze their cattle throughout the cropping season. Cattle are grazed in open communal rangelands around farmers' communities but also further away. During the dry season, the herdsmen corral the cattle on farmers' fields to graze on crop residue. Herdsmen are entitled to the milk produced by the cows as payment for their services.

Estimates of milk production from cattle is hard to retrieve since cows are not corralled at home and the milk goes to the Fulani herdsmen. Cattle are sold only in times of need for cash by the farmer. Sheep and goats are sold more frequently. Farmers sell between 3-5 sheep or goats per year.

Oxen are an important source of draught power for cropping during the rainy season. Wealthier farmers keep 2-4 oxen for draught power. Oxen are not only put to work on owners' fields but are also rented out to other farmers. Availability and access to fodder was a major determinant of farmers' ability to sustain oxen for draught power.

Table 6. Average livestock densities per farm type in Bunkure and Kachia local governments.

| | n[1] | Cattle | Sheep/goats | Pigs | Poultry | Work animals[2] |
|---|---|---|---|---|---|---|
| *Bunkure* | | | | | | |
| 1 | 35 | 3 | 26 | 0 | 29 | 0 |
| 2 | 35 | 11 | 47 | 0 | 106 | 0.5 |
| 3 | 24 | 17 | 69 | 0 | 106 | 0.3 |
| *Kachia* | | | | | | |
| 1 | 17 | 0 | 3 | 2 | 4 | 0 |
| 2 | 19 | 0 | 8 | 4 | 9 | 0 |
| 3 | 16 | 4 | 11 | 7 | 16 | 0 |

[1]Data from N2Africa Baseline Survey for Nigeria.

[2]Work animals include, donkeys, oxen and work bulls.

### *3.2.2 Kachia local government*

The most important crops in this community are ginger (*Zingiber officinale*), soybean, maize, groundnut, yam (*Dioscorea sp*) and cowpea. Ginger is the leading cash crop and was cultivated by all farmers that participated in this study. Yam and soybean are also important for income generation in that order. Other crops cultivated are sorghum, millet, melon seed (*Citrullus lanatus*), taro (*Colocasia esculenta*), okra and pepper. Farmers cultivate a combination of both commercial and food crops in complex cropping systems.

*Land tenure*

Land tenure and acquisition is arranged through inheritance as part of the customary law of the community. A patrilineal system of inheritance exists whereby the male off-springs are entitled to a piece of land for farming and settlement.

Earlier when the area was still largely uninhabited, individuals could attain a piece of virgin land by what is locally known as 'clearing of bush'. This means that as long as a piece of land is unoccupied, one is able to claim it for farming, settlement or both. This practise is currently not common since virgin land is either inaccessible (remote) or state owned. It is common for wealthier farmers purchase or rent part of the land on which they farm.

*Cropping systems*

Kachia local government experiences a 195 day growing period (LGP). Cropping is a mosaic of both cash and subsistence crops growing side by side. Two distinct field patterns were recorded during fieldwork; (1) ginger fields which intercropped with cereals and (2) relatively larger outfields that are sub-divided and each section planted to a single crop. Sections of such fields are also left fallow for one or more cropping seasons. Home fields are common to poor farmers where most of their farming activities are carried out.

Intercropping is practised in ginger with a cereal. In most cases this is either maize or sorghum. Grain legumes and yams are each planted as sole crops. Farmers rotate the sub-divided fields on an annual basis. Legumes are rotated with cereals and fallow plots. Some farmers owned plots close to rivers and streams and these were perceived to be more fertile. Farmers prioritised such fields for ginger and yam cultivation.

*Cropping calendar*

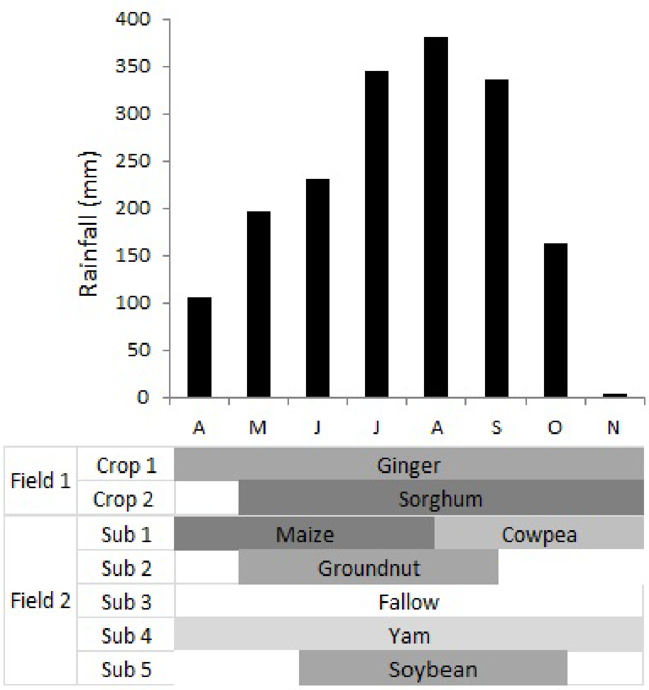


*Figure 4. Cropping calendar of Kachia showing rainfall pattern and cropping sequence of fields. Two major types of fields were recorded in this study site which are 1) the ginger field intercropped with a cereal and 2) the larger outfield planted with a diversity of crops or natural fallow.*

*Farm management activities*

Land preparation for cereal, legume, and yam cultivation starts in April when the rains commence. For ginger, land preparation is done after harvesting in the previous season. The field is ploughed and mulched over the dry season. Planting of ginger begins after the first good rains towards the end of April. Land preparation for cereal, legume and yam cultivation entails weeding or slashing of fallowed land. The cut vegetation is burnt on the field. Ridges are constructed manually. For yams, mounds (50-70 cm high) are constructed. Ridges are typically constructed 70-100 cm apart from each other and 25-40 cm high.

The bulk of planting begins in May for cereals and legumes. Yam can be planted earlier towards the end of April. However, intensive labour demand for mounding may delay planting till May and June. Due to this, it is a common practise that farmers construct mounds at the end of each cropping season in anticipation for the new season. If this is the case, mounds are mulched to preserve them. Maize and sorghum are sown in June in intercrop. The major legumes, soybean and groundnut, are planted at the end June through to mid-July. Cowpea is planted as a 'late' crop after the harvest of the first maize crop towards the end of August and the beginning of September.

The amount of weeding between planting and harvesting is crop dependent; ginger fields are weeded once after planting till the crop attains sufficient vegetative cover and is able to supress weeds. Cereals are either weeded once or twice depending on labour availability. Yams are mostly weeded twice and this is combined with reconstruction of mounds collapsed due to heavy rainfall. Weeding in legumes is done twice in all cases encountered. Application of insecticides in cowpea depends on incidence of insect pests.

Harvest begins with maize at the end of August through to September. Soybean and groundnut are harvested in October. Sorghum, 'late' cowpea and yams are harvested at the end of the rains in

November. Ginger is also harvested at this point but harvest depends on labour availability and the household need for cash. The crop can be left on the field till the next cropping season. In this case, the field is mulched with grasses to reduce evaporation and withering of the rhizomes.

*Livestock in farming systems*

The main livestock are sheep, goats and pigs. Cattle are reared by few wealthier farmers. Sheep and goats are corralled at the homestead and grazed on nearby communal pastures during day time. They are also fed with crop residue from home fields. Pigs are fed with purchased cereal bran or household food waste.

Piglets are purchased at the beginning of the cropping season and fattened throughout the season. At the beginning of the dry season, they are sold off. Farmers' ability to do this depends on available cash to purchase cereal bran and other feed. Wealthier farmers from Type 2 and 3 keep on average 5 pigs while poor farmers (Type 1) do not rear pigs due to demand for purchased feed. Farmers sell between 2-3 fattened sheep or goats per year.

The contribution of livestock and farmyard manure to cropping is less than in Bunkure local government (see Section 3.7). Farmyard manure from small ruminants is the most important organic fertilizer source in this local government. This manure is however predominantly applied to fields nearby the homestead.

### 3.3 Legumes in cropping systems

Legumes in cropping systems in northern Nigeria regard primarily grain and dual-purpose varieties of cowpea, groundnut, and soybean. Preference for type of legumes varied between studied sites. Cowpea is an important food crop in Bunkure and is therefore cultivated by a majority of farmers. Dual-purpose cowpea and groundnut is popular in Bunkure for their supply of fodder to feed livestock. 'Dan Bunkure' is popular dual-purpose cowpea variety appreciated by farmers in the region for its high fodder yield traits. The groundnut varieties Samnut 21 and 22 are also widely cultivated for grain and stover. Samnut 21 and 22 have been developed to fit the short growing period of the northern Guinea savannah zone (ICRISAT 2003). The cultivation of soybean was not as widespread as the other two grain legumes. Its inability to provide fodder and the poor availability of suitable varieties (e.g. early maturing varieties) to farmers in this region are reasons why less farmers cultivate the crop.

Cultivation of legumes in Kachia local government is primarily for income generation. Groundnut and soybean are the common legumes. Compared to Bunkure, there is less demand for legume residue to feed livestock since densities of livestock are lower in Kachia. Samnut 22 and the soybean variety TGx 1448-2E are widely grown by farmers.

Insect pests ranked high as a major constraint to legume production at both research locations. Especially in cowpea cultivation, Maruca pod borer is an important insect pest at both sites. Use of legume residue varied between the two study sites. All surveyed farmers from Bunkure collected legume residue from the fields and fed this to livestock. Groundnut residue followed by soybean was the most important legume residue for feeding livestock. The use of cowpea residue was limited since the crop sheds most of its biomass by the time of harvest. On the other hand, more than half (67%) of the farmers in Kachia left their legume residue in the field after harvesting. Sixteen per cent sell the residue to farmers with livestock, the remaining 16% feed legume residue to their own livestock.

Although no farmers were implementing inoculant technologies on their fields, awareness about the technology in Bunkure is around 57% of farmers compared to 11% in Kachia. Awareness on inoculant technology is through ICRISAT's Tropical Legumes II project and the N2Africa project. Input use (section

3.7) in legume cultivation is limited to farmyard manure and single superphosphate (SSP) fertilizer by some farmers. 48% (10 out of 21 in total) of farmers apply SSP to legumes in Bunkure whilst this is about 50% (9 out of 18 farmers) in Kachia. Few (Bunkure=10% and Kachia=11%) farmers said they apply either NPK and/or urea to legumes.

*Bunkure*

Land allocation to legumes varies very much by farm type. In general, the three major grain legumes occupy 36% of total farmers' cultivated land which is approximately 1.3 hectares per farm. Groundnut occupies 23% (0.9 ha) of total crop land followed by cowpea (14%/0.6 ha) and soybean (2%/0.05 ha). Cereals mostly sorghum and millet occupy the remaining 61% (circa 1 ha) of farm land across the three farm types.

Poor farmers (Type 1) cultivate major parcels of their land with cowpea after cereals. Cowpea is important to such low resource endowed farmers due to its function as a food crop. Groundnut is the main income generation crop for such farmers. Few farmers grow soybean.

Groundnut has the highest (23%, 0.9 ha) share of land among the legumes for medium resource endowed farmers (Type 2). Cowpea receives 8%. No fields growing with soybean were observed for this farm type during field work. Farmers from this type cultivate groundnut as the major income generation crop. Apart from groundnuts, surplus maize and sorghum is sold for income.

Wealthier farmers (Type 3) cultivate 25, 11, and 1% of their total land to groundnut, cowpea and soybean respectively. In terms of land size these are 1.5, 0.7, and 0.07 ha for groundnut, cowpea and soybean respectively. Due to higher land holdings by these type of farmers, they can cultivate bigger parcels of land to grain legumes as compared to medium and low resource endowed farmers. Wealthier farmers produce groundnuts and soybean for the market. They also sell part of their cereal produce as well as cowpea surpluses. Hence they are more market oriented.

*Kachia*

Besides cereals and legumes, farmers in Kachia cultivate ginger for income generation and yam for food as well as income. Groundnut and soybean are the common grain legumes produced for the market. Cowpea is also cultivated but mainly by wealthier farmers. Unlike in Bunkure local government, cowpea is cultivated predominantly for sale. Maize is the popular food cereal followed by sorghum. Millet was not observed on participating farmers' fields.

Resource poor farmers have very small land holdings of which more than half is cropped to cereals. Most poor farmers own 0.6 ha of land located close to the homestead where all crop production takes place. Land not occupied by cereals is preferably cropped to yam or ginger since these are lucrative crops in the region. Land allocation to legumes is 0.06 ha on average per farm and hence very low. Agricultural production is oriented towards food self-sufficiency.

Medium resource farmers have a balanced allocation of land to crops. Maize, ginger, yam and groundnut receive about 22% each of total land. Soybean and sorghum take up the rest of crop land about 6 and 3% respectively. These farmers produce for markets as well as for home consumption. Due to off-farm income generating opportunities, these farmers can purchase food on the market and therefore allocate land to lucrative cash crops.

Wealthier farmers target crop production for both home consumption and the market. They possess bigger landholdings and are able to produce simultaneously for household consumption and market. Most cowpea in Kachia is produced by wealthier farmers as a cash crop.

Table 7. Total crop allocation per farm type expressed in relation to total farm size given in hectares and percentages per farm type in Bunkure and Kachia local governments.

| Farm type | Crops | n | Land coverage (ha) | % coverage | n | Land coverage (ha) | % coverage |
|---|---|---|---|---|---|---|---|
| *Bunkure* | | | | *Kachia* | | | |
| Type 1 | Maize | 3 | 0 | NA | 3 | 0.24 | 41 |
| | Sorghum | | 0.63 | 41 | | 0.13 | 21 |
| | MIllet | | 0.19 | 12 | | 0 | 0 |
| | Groundnut | | 0.34 | 22 | | 0.03 | 5 |
| | Cowpea | | 0.36 | 24 | | 0 | 0 |
| | Soybean | | 0.03 | 2 | | 0.07 | 12 |
| | Ginger | | | | | 0.05 | 8 |
| | Yam | | | | | 0.07 | 13 |
| | total (ha) | | 1.5 | 100 | | 0.59 | 100 |
| | | | | | | | |
| Type 2 | Maize | 3 | 0.91 | 23 | 6 | 0.18 | 19 |
| | Sorghum | | 1.60 | 41 | | 0.03 | 3 |
| | Millet | | 0.20 | 5 | | 0 | 0 |
| | Groundnut | | 0.88 | 23 | | 0.25 | 26 |
| | Cowpea | | 0.31 | 8 | | 0 | 0 |
| | Soybean | | 0 | NA | | 0.06 | 6 |
| | Ginger | | | | | 0.21 | 22 |
| | Yam | | | | | 0.23 | 24 |
| | total (ha) | | 4.0 | 100 | | 1.0 | 100 |
| | | | | | | | |
| Type 3 | Maize | 6 | 0 | NA | 5 | 0.44 | 26 |
| | Sorghum | | 2.91 | 48 | | 0.18 | 11 |
| | Millet | | 0.87 | 14 | | 0 | 0 |
| | Groundnut | | 1.51 | 25 | | 0.15 | 9 |
| | Cowpea | | 0.68 | 11 | | 0.40 | 23 |
| | Soybean | | 0.07 | 1 | | 0.08 | 5 |
| | Ginger | | | | | 0.17 | 10 |
| | Yam | | | | | 0.29 | 17 |
| | total (ha) | | 6.04 | 100 | | 1.72 | 100 |

Table 8. Prevalent grain legumes and their respective varieties and characteristics at both research locations

| Crop | | Cultivar characteristics |
| --- | --- | --- |
| | *Bunkure* | |
| Soybean | TGx 1448-2E | Good *Striga hermonthica* control, medium maturing variety, low shattering rate of pods and preferred grain colour by farmers. |
| Groundnut | Samnut 21 | Adapted to Sudan and NGS, medium maturing, yield potential of over 2000 kg/ha |
| | Samnut 22 | Adapted to Sudan and NGS, medium maturing, potential grain yield of 2400 kg/ha and a high haulm yield. |
| Cowpea | Dan Bunkure | Adapted to specific AEZ conditions, and a dual purpose variety. |
| | IT90K-277-2 | Dual purpose variety. Adapted to the Sudan/northern guinea savannah. |
| | IT89KD-288 | Resistant to a range of diseases, dual purpose, and early maturing. |
| | Dan Ila | Medium maturing variety. Adapted to NGS and Sudan savannah. Photosensitive |
| | *Kachia* | |
| Soybean | TGx 1448-2E | Good *Striga* control, medium maturing variety, low shattering rate of pods and preferred grain colour by farmers. |
| | TGx 1835-10E | Early maturing and rust tolerant variety. |
| Groundnut | Samnut 22 | Adapted to Sudan and NGS, medium maturing, potential grain yield of 2400kg/ha and a high haulm yield. |

Source: IITA 2010 and ICRISAT 2003.

### 3.4 Crop productivity

Interviews with participating farmers revealed key problems constraining crop productivity at study sites (Figure 5). In Bunkure local government, *Striga hermonthica* and *Striga gesneroides* combined was reported by approximately 24% of all farmers and incidence of the parasitic weed on fields was 22% (7 out of 31 monitored fields). Insect pests for example Maruca pod borer in cowpea is an important limiting factor to crop yields in Bunkure local government. 62% of farmers said their cowpea cultivation was threatened by Maruca.

Insect pests in legume cultivation also occur in Kachia and at a similar level of prevalence. Striga incidence was not encountered on monitored fields and neither did farmers report this as a problem. Other important problems linked to crop productivity by farmers in Kachia are destruction of crops by torrential rains and termite destruction of cereals in the field.

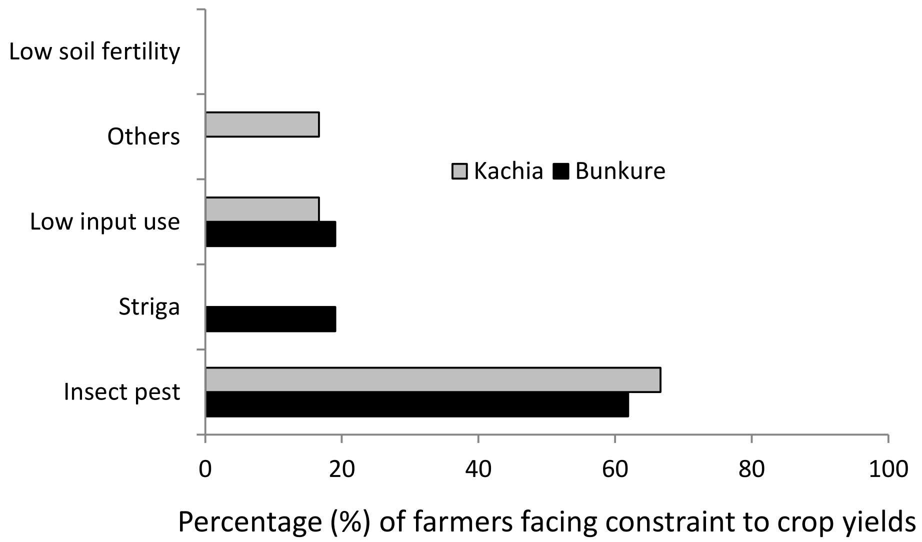


*Figure 5. Major constraints to farmers' crop yields in Bunkure and Kachia local governments.*

Table 9. Summary of average crop productivity per study site. Data is from participating farmers' fields sampled and yield estimates subject to current crop being cultivated.

| | *Bunkure* | | | *Kachia* | | |
|---|---|---|---|---|---|---|
| Crop | n | Grain (t ha$^{-1}$) | Stover (t ha$^{-1}$) | n | Grain (t ha$^{-1}$) | Stover (t ha$^{-1}$) |
| Maize[2] | 0 | NA | NA | 10 | 4.3 | |
| Sorghum[2] | 10 | 5.9 | | 4 | 1.4 | |
| Millet[2] | 6 | 5.2 | | 0 | NA | |
| Groundnut | 9 | 2.1 | 4.3 | 4 | 1.6 | 2.6 |
| Cowpea | 5 | 1.7 | 3.5 | 2 | 1.2 | 2.4 |
| Soybean | 2 | 1.3 | 2.0 | 4 | 2.1 | 1.8 |
| Ginger | | | | 3 | 16.7[2] | |

[1]NA, data not available since no fields with particular crop were sampled.

[2]Cereal yields are presented in fresh weight (FW) at ripe harvest stage.

[3]Ginger yield is given in fresh weight (FW)

Sorghum was the common cereal grown at both study sites. Farmers in Bunkure did not grow maize during the time of fieldwork. In Kachia, participating farmers were not cultivating millet during this study. Yam and ginger are not cultivated in Bunkure. Average yield of sorghum in Bunkure is 6.7 t ha$^{-1}$ and four times as high as in Kachia. The common variety of maize in Kachia was Oba-Super II (Waddington, Pixely et al. 1997) and this gives good yield of up to 4.8 t ha$^{-1}$ on farmers' fields.Cowpea and groundnut yields in Bunkure are higher than in Kachia. Kachia however records higher yields of soybean.

Crop production is also presented by farm type to get an impression of actual output per farm (Table 10).

Table 10. Crop production at farm level for cereals, legumes and ginger given in t $farm^{-1}$.

| | n | Farm size (ha) | Cereals | Cowpea | Groundnut | Soybean | Ginger[1] |
|---|---|---|---|---|---|---|---|
| *Bunkure* | | | | | | | |
| Type 1 | 3 | 2.7 | 2.2 | 0.6 | 1.3 | 0.075 | |
| Type 2 | 2 | 4.0 | 8.1 | NA | 1.5 | 0.081 | |
| Type 3 | 3 | 6.0 | 17.0 | 1.5 | 8.1 | NA | |
| *Kachia* | | | | | | | |
| Type 1 | 2 | 0.6 | 0.6 | 0 | 0 | 0 | 0.53[1] |
| Type 2 | 4 | 1.0 | 1.2 | 0 | 0.3 | 0.4 | 1.94[1] |
| Type 3 | 5 | 1.6 | 2.9 | 1.2 | 0.6 | 0.6 | 1.80[1] |

[1]Ginger produce is given in fresh weight (FW).

### 3.5 Quantifying grain legume productivity and BNF

*BNF in cowpea, groundnuts and soybean*

N contribution from biological $N_2$ fixation to grain legumes in Bunkure ranged from 44 to 93% in cowpea and 43 to 91% for groundnut. Soybean in Kachia obtained between 46 and 76% of its N from $N_2$ fixation whereas groundnut obtained between 21 and 29%. In general, cowpea fixed the highest amount of N followed by soybean then groundnut. $N_2$ fixation levels in Bunkure were however higher than in Kachia. On a study site differentiation, Bunkure receives significantly higher ($P = 0.017$) contributions of N from $N_2$ fixation than Kachia. Crop specific $N_2$ fixation did not differ significantly.

$N_2$ fixation was estimated from aboveground plant biomass although recent evidence from the literature suggests that, substantial amount of fixed N remains in the rhizosphere (Laberge, Franke et al. 2009). Wichern *et al* (2008) estimated that 30% of the total N from $N_2$ fixation. Using this estimation, circa 120 and 93 kg N $ha^{-1}$ is fixed by cowpea and groundnut respectively in the above and belowground plant parts in Bunkure. For Kachia total N from fixation in the above and belowground plant parts is then 85 kg N $ha^{-1}$ in soybean and 40 kg N $ha^{-1}$ in groundnut. Deposition of N from $N_2$ in the rhizosphere is relevant to the overall N economy of the field and farm. Cereal intercropped with legumes might benefit directly from $N_2$ fixation and subsequent crops can benefit from residual effect of legumes (Fujita, Ofosu-Budu et al. 1992).

Table 11. Productivity and N content of grain legumes measured at the study sites.

| | n | DM production (t $ha^{-1}$) | | | Total aboveground N in crop (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | Grain | Stover | Total | Grain | Stover | Total |
| *Bunkure* | | | | | | | |
| Cowpea | 4 | 2.7 | 3.6 | 6.3 | 95 | 39 | 134 |
| Groundnut | 4 | 1.2 | 3.0 | 4.2 | 69 | 21 | 90 |
| *Kachia* | | | | | | | |
| Soybean | 4 | 2.2 | 2.1 | 4.3 | 78 | 15 | 93 |
| Groundnut | 2 | 1.5 | 3.7 | 5.2 | 86 | 26 | 112 |

Table 12. N contribution from biological $N_2$ fixation to grain legume cultivation.

| | n | Total N in crop (kg ha$^{-1}$) | | | N from BNF (kg ha$^{-1}$) | | | %Ndfa | δ $^{15}$N | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Grain | Stover | Total | Grain | Stover | Total | | Legume | Reference |
| *Bunkure* | | | | | | | | | | |
| Cowpea | 4 | 95 | 39 | 134 | 74 (33-109) | 30 (14-45) | 104 | 76 (44-93) | -0.57 | 2.53 |
| Groundnut | 4 | 69 | 21 | 90 | 50 (19-110) | 15 (6-33) | 65 | 72 (43-91) | -0.47 | 3.08 |
| *Kachia* | | | | | | | | | | |
| Soybean | 4 | 78 | 15 | 93 | 49 (20-75) | 9 (4-14) | 60 | 63 (46-76) | -0.18 | 2.27 |
| Groundnut | 2 | 86 | 26 | 112 | 21 (18-24) | 6 (5-7) | 28 | 25 (21-29) | 0.08 | 1.71 |

Minimum and maximum values given in parenthesis.

### 3.6 Soils and soil fertility

FAO in (Ogungbile 1999) classifies soils in northern Nigeria as Lithosols. In Bunkure and its surroundings, soils are dominantly ferruginous, developed from sandy material (rock). Most of these soils have a composition of up to 80% sand. In and around Kachia, the soils are developed from crystalline acid rocks and highly ferruginous. These soils are generally shallow and poorly developed.

Table 13. Physico-chemical parameters of soil fertility shown for the 3 farm types in Bunkure and Kachia local government.

| | n | pH | %OC | %N | Olsen P (ppm) | ECEC (cmol kg$^{-1}$) | | | | | %SAND | %SILT | %CLAY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Bunkure* | | ($H_2O$) | | | | Ca | Mg | K | Na | ECEC | | | |
| 1 | 5 | 6.3 | 0.32 | 0.028 | 1.1 | 1.82 | 0.77 | 0.14 | 0.10 | 2.84 | 71 | 17 | 12 |
| 2 | 8 | 6.3 | 0.31 | 0.030 | 1.5 | 2.00 | 0.88 | 0.16 | 0.10 | 3.14 | 73 | 16 | 11 |
| 3 | 16 | 6.1 | 0.27 | 0.028 | 2.0 | 1.59 | 0.76 | 0.13 | 0.11 | 2.59 | 76 | 13 | 11 |
| *Kachia* | | | | | | | | | | | | | |
| 1 | 6 | 6.1 | 1.36 | 0.137 | 2.2 | 2.76 | 0.97 | 0.20 | 0.09 | 4.02 | 57 | 19 | 24 |
| 2 | 7 | 5.4 | 0.96 | 0.091 | 2.4 | 1.96 | 0.81 | 0.15 | 0.10 | 3.02 | 53 | 21 | 26 |
| 3 | 5 | 5.5 | 1.09 | 0.105 | 1.7 | 1.95 | 1.41 | 0.18 | 0.12 | 3.67 | 55 | 22 | 23 |

Soil pH is satisfactory at both study sites. Bunkure had an average pH of 6.2 whilst Kachia was 5.7. At Bunkure, poor and medium resource endowed farmers had similar pH of 6.3. Wealthier farmers had a lower pH of 6.1. pH of poor, medium and wealthier farmers' fields in Kachia was 6.1, 5.4, and 5.5 respectively. Average organic carbon and total N were low for all farmers in Bunkure at 0.3% and 0.028% respectively. Available P at this site was 1.5 ppm, well below the critical level of 10 ppm. Total effective cation exchange capacity (ECEC) was 2.85 cmol kg$^{-1}$. Across farm types, level of K was low between 0.13 and 0.16, lowest for wealthier farmers and highest on medium farmers' fields. Fertility of the soil in Bunkure are below critical levels. The low clay content of soils at Bunkure is an indication of low clay activity and association between clay minerals and organic carbon which are linked in soils (Stenberg 1997).

From the analysed soil data, fertility of soils is higher in Kachia. Clay content was on average 24% and average organic carbon at 1.1%. Poor farmers' fields had the highest chemical indicators of soil fertility except in the case of available P. Overall site average organic carbon, total N, and available P were 1.14%, 0.11%, and 2.1 ppm respectively. Total ECEC was 3.57 cmol $kg^{-1}$. Exchangeable K was just below the critical level (0.2 cmol $kg^{-1}$) at 0.17 cmol $kg^{-1}$.

Table 14. Physico-chemical soil fertility indicators for Kachia local government based on crop cultivated in the current cropping season of 2011.

| Crop | n | pH (H2O) | %OC | %N | Olsen P (ppm) | Ca | Mg | K | Na | ECEC | %SAND | %SILT | %CLAY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | cmol $kg^{-1}$ | | | | | | | |
| Cowpea | 2 | 5.5 | 0.85 | 0.070 | 1.5 | 3.2 | 0.97 | 0.23 | 0.16 | 4.5 | 52 | 24 | 24 |
| Groundnut | 2 | 5.4 | 0.85 | 0.076 | 1.8 | 1.5 | 0.47 | 0.11 | 0.08 | 2.2 | 55 | 20 | 25 |
| Ginger | 3 | 6.1 | 1.06 | 0.100 | 1.9 | 1.5 | 0.44 | 0.11 | 0.10 | 3.6 | 52 | 22 | 26 |
| Maize | 3 | 5.2 | 1.07 | 0.109 | 2.7 | 2.5 | 0.81 | 0.18 | 0.10 | 2.7 | 51 | 22 | 28 |
| Mixed[1] | 4 | 6.2 | 1.46 | 0.143 | 2.1 | 1.9 | 0.57 | 0.14 | 0.09 | 4.5 | 58 | 20 | 22 |
| Soybean | 2 | 5.2 | 0.83 | 0.076 | 3.5 | 3.2 | 1.03 | 0.23 | 0.10 | 2.2 | 52 | 20 | 28 |
| Yam[2] | 2 | 5.4 | 0.78 | 0.069 | 1.2 | 2.4 | 0.77 | 0.17 | 0.11 | 3.5 | 59 | 23 | 18 |

[1]Mixed refers to fields intercropped with maize/sorghum and soybean.
[2]Two yam fields situated close to streams are perceived by farmers to be more fertile than their other fields.

Fields intercropped with sorghum and soybean ('Mixed' fields) seem to be the most fertile with highest organic carbon, total N and ECEC. Ginger and maize fields were also more fertile than grain legume and yam fields. Soybean fields had highest available P whilst cowpea alongside 'mixed' fields had highest ECEC. Available P and exchangeable K for all crop fields were still below critical fertility thresholds. pH on all fields was satisfactory within the ranges of 5.2 and 6.2. Clay content of fields was similar across crops but lowest on fields cropped to yam. This is unexpected since most yam fields are located nearby streams where clay content can be expected to be higher.

Soil fertility by crop (Table 14) is based on crop in the current season. Cropping history is a more appropriate determinant of soil fertility. Farmers practise rotation on their fields on an annual or 2 year basis. Cereal and mixed fields are usually rotated with legume fields. Ginger and yam fields are rotated with each other or with natural fallows.

Table 15. Soil fertility indicators grouped for home/close fields, intermediate and distant fields in Kachia local government.

| | Home/Close | Intermediate | Distant | $P_{(0.05)}$ | $LSD_{(0.05)}$ |
|---|---|---|---|---|---|
| OC (%) | 1.46 | 0.830 | 0.91 | < 0.001 | 0.24 |
| N (%) | 0.148 | 0.079 | 0.081 | < 0.001 | 0.026 |
| P (ppm) | 2.3 | 2.2 | 1.5 | 0.66 | 1.8 |
| K (cmol kg) | 0.22 | 0.14 | 0.16 | 0.42 | 0.54 |
| CEC (cmol kg) | 4.46 | 2.82 | 3.25 | 0.32 | 1.92 |
| n | 5 | 4 | 9 | | |
| Average distance[1] (km) | 0.06 | 0.22 | 1.53 | | |

[1]Average distance of field from the homestead of the farmer.

ANOVA analysis was also performed on soil data from Kachia based on farm types and crop allocation to fields (Table 15). No significant differences were obtained. Further analysis (ANOVA) based on field distance from the homestead was conducted. Data are displayed for the important indicators namely OC, N, P, K and CEC. At a 5% significance level, OC and N differed highly significantly between close fields and intermediate and distant fields. Intermediate fields and distant fields did not differ from each other in terms of OC and N. Levels of P and K and the ECEC did not show any significant differences between the field types

*Soil fertility management practices*

*Bunkure*

In Bunkure local government, manure from livestock is an important source of nutrients for crop production and remains the major source of replenishing nutrients to fields that are continuously cropped. Manure is available in the form of cattle waste and farmyard manure from goats and sheep. After crops harvests, farmers grant access to cattle to graze on crop stubble. Manure is deposited on the fields by grazing cattle and this is incorporated into the soil during land preparation.

Farmyard manure comprises household waste, livestock faeces and fodder residues. The manure is collected in heaps outside the homestead throughout the growing season and transported by donkey or oxen carts during land preparation at the beginning of the cropping season where it is incorporated into the soil. This type of manure is predominantly made up of faeces and urine from small ruminants and remains of feed and fodder.

*Kachia*

Cattle densities in the southern Guinea savannah are lower and so is the availability of manure for application to fields. Fallow rotations are an important practise used for soil fertility management. Approximately 60% of all farmers surveyed practise fallowing. Durations of fallow periods varied between a single cropping season to about 5 years maximum (2.8 years on average). A drawback in this study is that fallow fields were not measured for an impression of their contribution to total farm size.

Farmers use farm yard manure although this is available in lower quantities. Manure is applied to close and home fields only. Poor farmers who cultivate one field usually located near the homestead can apply all their farmyard manure to that field. This gives rise to the higher organic carbon (OC) levels of home fields in relation to middle and distant fields. Manure application is carried out at various intervals during the cropping season.

**3.7 Input use**

*Organic and inorganic inputs*

Average use of organic manure in Bunkure is an estimated 1.6 t $ha^{-1}$. All three farmer types purchase NPK (15:15:15) and urea fertilizers of approximately 45 and 41 kg $ha^{-1}$ each. Use of single superphosphate (SSP) is lower at 8 kg $ha^{-1}$. Wealthier farmers use the least amounts of inorganic fertilizers in Bunkure. They had access to more organic fertilizers due to ownership of more livestock.

Wealthier farmers in Kachia compensate for low availability of organic fertilizer by applying NPK and urea fertilizers. Medium resource endowed farmers mainly apply NPK and urea. Poor farmers in Kachia rely only on organic inputs in crop production.

Table 16. Summary of organic and inorganic fertilizer use in kg ha$^{-1}$ averaged for farm types. Nutrient content in kg ha$^{-1}$ also given.

| Farm type | n | Fertiliser application rate | | | | Nutrient application rate | | |
|---|---|---|---|---|---|---|---|---|
| | | Manure | NPK | Urea | SSP | N | P | K |
| *Bunkure* | | | | | | | | |
| 1 | 6 | 994 | 47 | 51 | 6 | 39 | 9 | 21 |
| 2 | 7 | 1848 | 53 | 44 | 12 | 45 | 13 | 34 |
| 3 | 8 | 1996 | 35 | 39 | 5 | 41 | 10 | 34 |
| *Kachia* | | | | | | | | |
| 1 | 4 | 174 | 38 | 25 | 16 | 18 | 7 | 8 |
| 2 | 8 | 85 | 73 | 40 | 15 | 30 | 12 | 12 |
| 3 | 6 | 279 | 134 | 104 | 49 | 70 | 24 | 24 |

NPK applied as NPK 15:15:15 (nutrient contents calculated as 15:12:15)
P in $P_2O_5$ = 0.43638
K in $K_2O$ = 0.83015
Urea N content =46%
P supplied as single super phosphate SSP (7% P)
Nutrient content of livestock faeces and farm yard manure derived from Hoffman *et al* 2001;
Nitrogen in livestock faeces = 1.9% and in farmyard manure =0.89%
P in livestock faeces = 0.9% and in household manure = 0.24%
K in livestock faeces = 0.54% and household manure = 1.45%

Livestock and household manure application in Bunkure is targeted to staple cereals and the major cash crop groundnut. Cowpea receives less manure. The fields on which soybean is cultivated seem to receive less organic inputs but this should be evaluated with caution since only few of the sampled fields had soybean growing on them. NPK and urea fertilizers are only applied to cereals and not legumes. SSP is the only inorganic fertilizer farmers apply in legume cultivation. Among legumes, farmers apply most SSP to groundnut which is the commercial legume.

Organic inputs are targeted to cereals and cash crops in Kachia. Application of inorganic fertilizers NPK, urea and SSP occurs in all cereal and cash crops although rates of application differ. As in Bunkure, SSP is the only inorganic fertilizer applied to legumes. Cowpea receives organic fertilizers comparable to the rates of cereals and cash crops. Soybean, cowpea, and groundnut receive SSP in that decreasing order.

Table 17. Organic and inorganic fertilizer inputs to crops in Bunkure and Kachia local government. Estimated application levels for all displayed inputs are presented in kg $ha^{-1}$.

| Crop | n | Fertiliser application rate | | | | Nutrient application rate | | |
|---|---|---|---|---|---|---|---|---|
| | | Manure | NPK | Urea | SSP | N | P | K |
| *Bunkure* | | | | | | | | |
| Sorghum | 11 | 495 | 74 | 76 | 0 | 50 | 6 | 16 |
| Millet | 7 | 369 | 106 | 98 | 29 | 64 | 10 | 18 |
| Maize | | NA[1] | NA | NA | NA | NA | NA | NA |
| Cowpea | 4 | 242 | 0 | 0 | 38 | 2 | 3 | 4 |
| Groundnut | 5 | 485 | 0 | 0 | 40 | 4 | 4 | 7 |
| Soybean | 2 | 131 | 0 | 0 | 6 | 1 | 1 | 2 |
| *Kachia* | | | | | | | | |
| Sorghum | 5 | 225 | 38 | 25 | 25 | 19 | 5 | 8 |
| Millet | | NA[1] | NA | NA | NA | NA | NA | NA |
| Maize | 9 | 50 | 53 | 10 | 9 | 13 | 4 | 7 |
| Cowpea | 2 | 271 | 0 | 0 | 30 | 2 | 3 | 4 |
| Groundnut | 4 | 0 | 0 | 0 | 10 | 0 | 1 | 0 |
| Soybean | 4 | 0 | 0 | 0 | 86 | 0 | 6 | 0 |
| Yam | 2 | 0 | 166 | 69 | 74 | 57 | 16 | 21 |
| Ginger | 5 | 188 | 40 | 33 | 27 | 23 | 5 | 8 |

[1]Data not available for these crops. Fields not sampled during survey.

Organic input application in Bunkure is highest for intermediate fields and lowest on home/close fields. The amount of manure applied to fields is not dependent on the distance of the field to the homestead although this can be expected due to labour needed to transport manure to distant fields (Tittonell, Vanlauwe et al. 2005). In Bunkure however the semi-arid savannah landscape is typically flat which makes transport, often with draught animals relatively easy.

Organic input use in Kachia is highest on home and close fields and lowest on distant fields. Many fields are far from the homestead contributing to increased labour and costs of transporting manure to these fields. The use of draught animals for transportation in Kachia was also not encountered during field work. This is also coupled to lower manure availability due to lower livestock densities. Farmers apply manure to fields closer to the homestead that can be managed more intensively. NPK and urea application rates are higher on home fields and lowest on intermediate fields. The highest application rates of SSP fertilizer occur on distant fields followed by home fields. SSP application (kg $ha^{-1}$) is high for distant fields which are often cropped with yam. Yam receives the highest application of SSP.

Table 18. Input application on a field category basis for the two study sites.

| Field type | n | Field distance[1] (km) | Application rate (kg ha$^{-1}$) | | | | Mineral content (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Manure | NPK | Urea | SSP | N | P | K |
| *Bunkure* | | | | | | | | | |
| Home field | 3 | 0.11 | 625 | 83 | 50 | 33 | 41 | 9 | 19 |
| Intermediate | 4 | 0.40 | 975 | 188 | 200 | 63 | 129 | 19 | 37 |
| Distant | 8 | 1.15 | 843 | 100 | 100 | 45 | 69 | 12 | 25 |
| *Kachia* | | | | | | | | | |
| Home field | 3 | 0.06 | 300 | 87 | 40 | 33 | 34 | 9 | 15 |
| Intermediate | 3 | 0.22 | 250 | 33 | 0 | 0 | 7 | 3 | 8 |
| Distant | 15 | 1.53 | 36 | 40 | 19 | 46 | 15 | 6 | 6 |

[1]This is measured distance from farmers' homesteads to their fields. Measurements are by Waypoints using GPS device.

*Chemical control*

Use of glyphosate based herbicides is common during land preparation for the cultivation of cereals at both study sites. Wealthier farmers from Type 2 and 3 in Bunkure use on average 0.5 L ha$^{-1}$ of herbicides during land preparation. In Kachia, farmers from all types use herbicides for land preparation. Poor farmers use close to 1 L ha$^{-1}$ (0.9 L ha$^{-1}$) of herbicides. Wealthier farmers in Type 2 and 3 use 1.3 L and 2.7 L ha$^{-1}$ respectively. Herbicide use in land preparation is higher in Kachia because tilling of the soil is much more tedious. Soils in Kachia have a higher clay content, presence of stones and a more robust vegetation make land preparation more tedious as compared to Bunkure.

The main insecticides used by farmers are Karate-Z with active ingredient Lamda – Cyhalothrin (22%), and other Cypermethrin (5-7%) and dimetheoate-based insecticides. Insecticides are used during cowpea cultivation to control insect pests as Maruca pod borer. Which is important in these agro-ecological zones. Application of insecticides in Bunkure are as follows: 0.3 L, 0.5 L and 0.3 L ha$^{-1}$ for poor, medium and high resource endowed farmers respectively. For Kachia, the estimated application rates are 0.9 L, 0.92 L and 1.1 L ha$^{-1}$ for poor, medium and high resource endowed farmers respectively. The above given application rates are litres of concentrate herbicides and insecticides and not the diluted formulae applied to fields.

*Labour*

Farmers make selective use of hired labour in Bunkure. Use of hired labour is dependent on type of crop and management activity. Land preparation is a typical activity for which labour is hired. So is weeding and mending of ridges. Planting, application of herbicides and chemical control, and harvesting are done using household labour. Certain labour intensive crops on the other hand demand hired labour. Groundnut and soybean are crops for which labour is commonly hired during harvesting and threshing. Food crops as maize, sorghum ad millet require less labour. No labour is hired for cowpea production.

Table 19. Labour input in hours per hectare (h $ha^{-1}$) for major farming and farm management activities in Bunkure local government.

| | n | Land preparation | Planting | $2^{nd}$ weeding | Application of chemical control | Harvesting | Total |
|---|---|---|---|---|---|---|---|
| HH | 6 | 311 | 264 | 340 | 11 | 211 | 1137 |
| Hired | 6 | 211 | 0 | 242 | 0 | 148 | 601 |
| Total (hrs) | | 522 | 264 | 582 | 11 | 359 | 1738 |

Labour is divided between hired and presented as average for all farm types. Weeding involves re-ridging of damaged ridges as a result of run-off during rains. Harvesting excludes threshing in for example groundnuts.

Household labour was the most important source for farming activities in both study sites. For poor farmers in Kachia, this was the only source of labour available to them. Medium resource endowed farmer occasionally hired labour. For wealthier farmers who were permanently employed off farm, hired labour is always needed to supplement available household labour.

Major labour demanding crops in Kachia are ginger, yam, groundnut, and soybean. Hired labour in this local government is used in all activities from land preparation, ridging/mounding, planting, weeding and harvesting. Postharvest activities such as threshing in groundnuts and drying of ginger also require hired labour by farmers with relatively large fields. Detailed information on labour inputs for Kachia is displayed below.

Table 20. Summary of household and hired labour in hours per ha (h $ha^{-1}$) for farm Types 1, 2 and 3 in Kachia local government.

| Hired labour | n | LND prep | Planting | 1st weeding | 2nd weeding | 3rd weeding | Harvesting |
|---|---|---|---|---|---|---|---|
| 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 5 | 279 | 211 | 183 | 202 | 17 | 284 |
| 3 | 3 | 346 | 45 | 135 | 127 | 49 | 581 |
| | | | | | | | |
| HH labour | | LND prep | Planting | 1st weeding | 2nd weeding | 3rd weeding | Harvesting |
| 1 | 4 | 212 | 172 | 125 | 106 | 0 | 508 |
| 2 | 5 | 257 | 179 | 432 | 101 | 0 | 2611 |
| 3 | 3 | 325 | 325 | 216 | 247 | 0 | 433 |
| | | | | | | | |
| Total | | LND prep | Planting | 1st weeding | 2nd weeding | 3rd weeding | Harvesting |
| 1 | 4 | 212 | 172 | 125 | 106 | 0 | 508 |
| 2 | 5 | 535 | 390 | 615 | 303 | 17 | 2895 |
| 3 | 3 | 670 | 370 | 352 | 375 | 49 | 1013 |

Values regarding labour input by farmers are estimations from the previous cropping season. These values seem rather large and unrealistic if calculated in terms of days per year. Hence values should be interpreted with caution and only used as an indication of the high labour demand in farming activities. Estimation of labour inputs given above used to give an impression of the investments in labour relative to other inputs such as improved seeds, fertilizer, and chemicals.

*Others inputs*

Purchase of seeds was low in Bunkure local government. Nineteen per cent of the farmers purchase seeds for planting. The majority either save their own seed or obtain it from family and other members of the community. Especially for subsistence cereal crops and cowpea, purchase of seeds was non-existent. This research considers purchase of seeds as the monetary exchange for improved and packaged seed from a market or government outlet. So hence, if a farmer would exchange seeds with a counterpart, this was not considered as purchase. Commonly purchased improved seeds were maize and groundnut in Bunkure. Purchase of seed input was also not linked to resource endowments as would have been expected. In this local government, farmers that purchase improved seed were from all farm types.

On the other hand, 61% of farmers in Kachia purchase improved seeds of one kind or the other. Of this 61%, input purchase was divided equally between medium and high resource endowed farmers. Poor farmers do not purchase improved seeds. Improved seeds of maize are the most common seed input followed by groundnut and soybean.

### 3.8 Crop and farm level nutrient balances

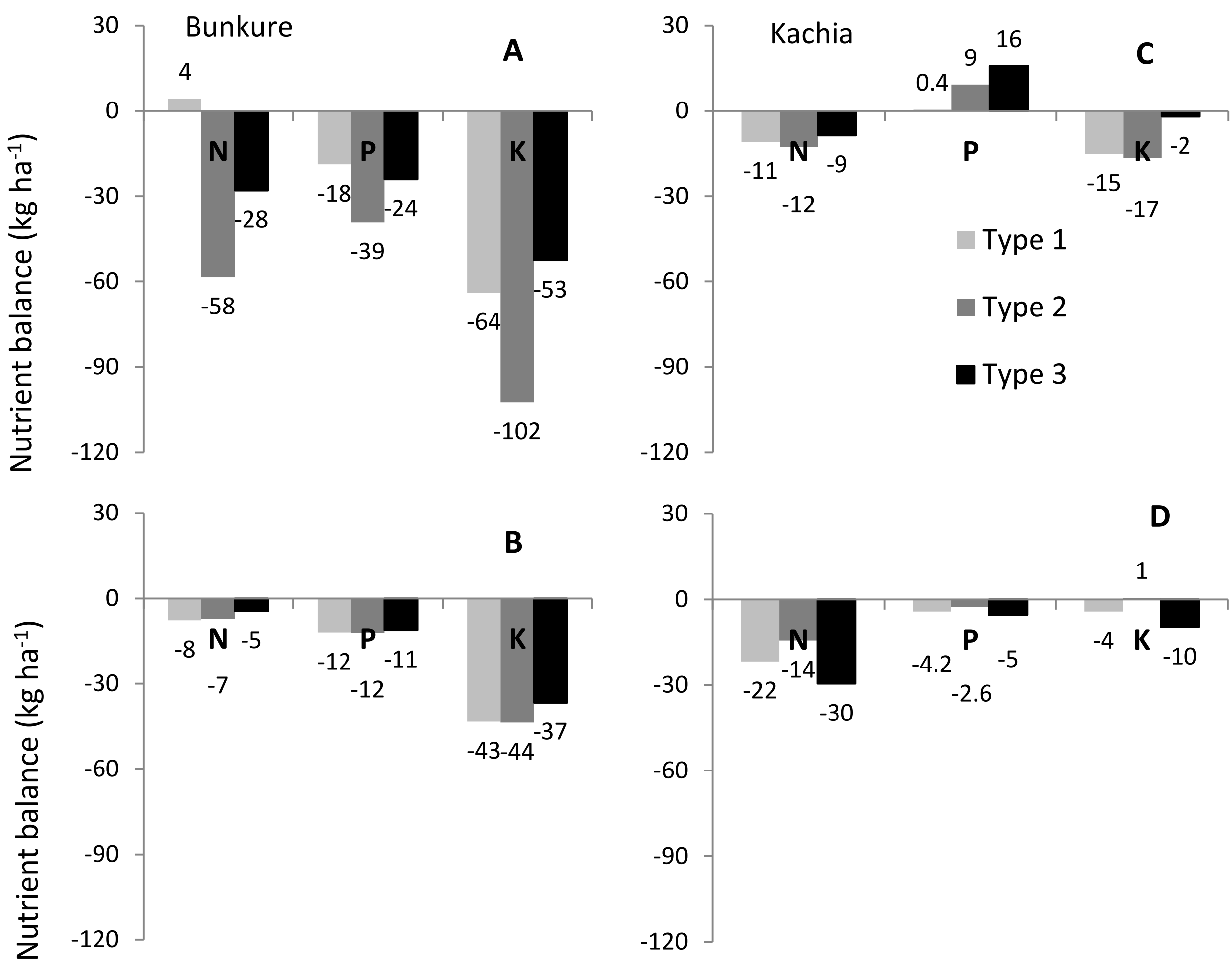


*Figure 6. Nutrient budgets at Bunkure and Kachia distinguished for cereal (A and C) and grain legumes (B and D).*

Further assumptions were made in order to calculate nutrient balances and these are as follows; in Bunkure local government, farmers remove both legume and cereal crop residue from the fields after harvesting of the grain. In Kachia, farmers leave residue of cereals in the field after harvesting. However, these residue are eventually grazed by livestock of agro-pastoralist herdsmen during the dry season. Sixty seven per cent of farmers leave their crop residue on the field after harvesting. This was taken as the benchmark.

Nutrient balances for all three elements were negative at Bunkure local government. Balances were -17, -20, and -57 kg $ha^{-1}$ $year^{-1}$ for N, P and K respectively. Despite substantial input of K into farm systems by harmattan dust, K has the highest deficit at farm level in Bunkure. Reasons for this are not only due to removal of crop residue but also high yields of cereals. Nutrient balances in Kachia were also negative for N and K, -16 kg and -8 kg $ha^{-1}$ $year^{-1}$ respectively. P balances in Kachia were the only positive values at both study sites at 2 kg P $ha^{-1}$ $year^{-1}$. N budgets in Kachia are less negative than Bunkure. This is a result of lower cereal yields and different management strategy of legume residue.

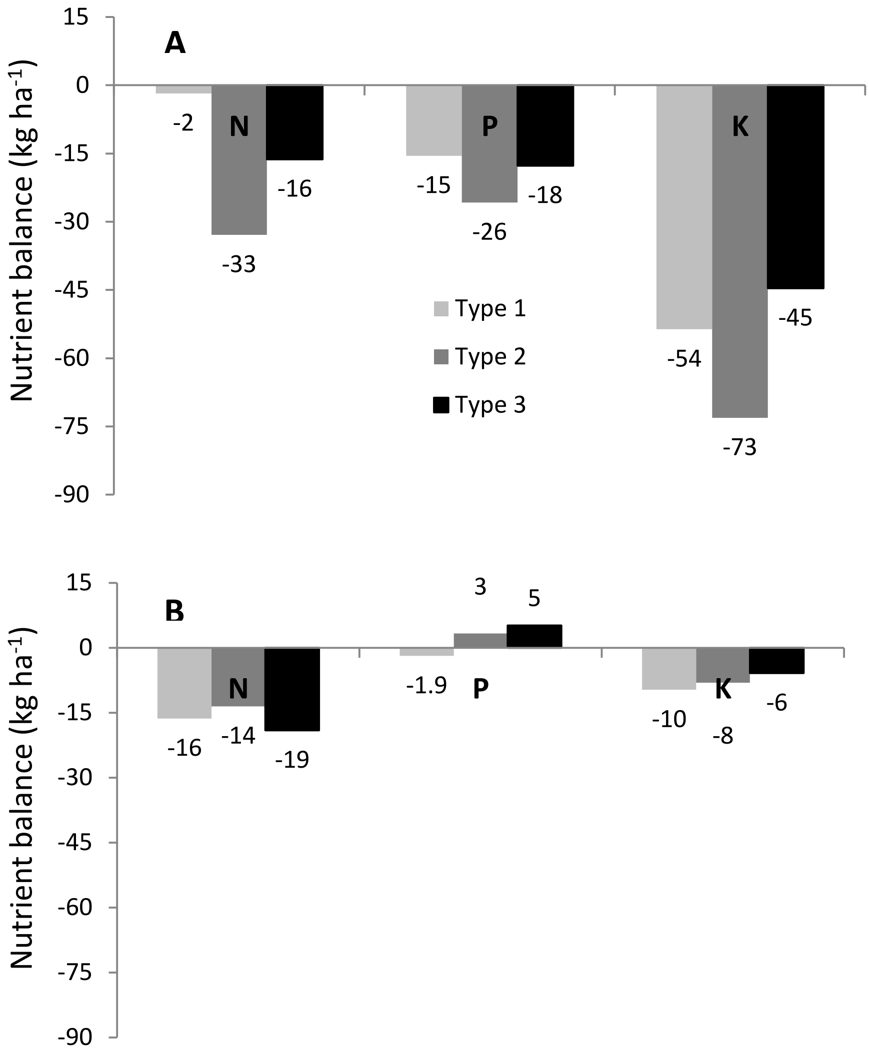


*Figure 7. Farm level nutrient balances for N, P and K for all three farmer typologies at both study sites (A) Bunkure and (B) Kachia local governments.*

### 3.9 Food self-sufficiency

Table 21. Total food production (TFP) and consumption (TFC) per farm matched with food available per household member (HHm) and food requirements in energy and protein terms.

| | n | Farm size (ha) | HH size | Land HHm$^{-1}$ (ha) | TFP[1] (t farm$^{-1}$) | TFP (t ha$^{-1}$) | TFC[2] (t farm$^{-1}$) | Food HHm$^{-1}$ (kg) | Energy (Kcal HHm day$^{-1}$) | Protein (g HHm day$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| *Bunkure* | | | | | | | | | | |
| Type 1 | 3 | 2.7 | 21 | 0.13 | 4.0 | 1.5 | 3.7 | 192 | 2146 | 96 |
| Type 2 | 2 | 4.0 | 29 | 0.14 | 9.6 | 2.4 | 5.5 | 331 | 3696 | 166 |
| Type 3 | 3 | 6.0 | 36 | 0.17 | 26.6 | 4.4 | 6.4 | 739 | 8247 | 370 |
| *Kachia* | | | | | | | | | | |
| Type 1 | 2 | 0.6 | 8 | 0.06 | 0.6 | 1.1 | 1.6 | 77 | 859 | 39 |
| Type 2 | 4 | 1.0 | 12 | 0.08 | 1.4 | 1.4 | 2.2 | 121 | 1348 | 60 |
| Type 3 | 5 | 1.6 | 18 | 0.09 | 4.8 | 3.0 | 3.6 | 265 | 2957 | 133 |

[1]TFP is Total Food Production of edible crops and parts. Soybean and ginger are excluded from food production estimations. DM corrections are made with values from the literature.
[2]TFP is Total food Consumption which is the total amount of food required to supply all household members with sufficient energy (21 Kcal day$^{-1}$) and proteins (95 g day$^{-1}$) throughout the year.

Average production of food crops per farm, i.e. cereals and legumes excluding soybean is higher in Bunkure than in Kachia. This is also matched by the higher household sizes in Bunkure, thus demanding more food. In Bunkure food production per farm increases from poor to wealthier farmers. Wealthier farmers (Type 3) own twice as much land as poor counterparts (Type 1) and their productivity is much higher. Higher application rates of organic fertilizers coupled to higher available labour for more intensive management activities are plausible reasons for the big differences. At Kachia, production per farm also increases with increasing resource endowments. The same is true in terms of productivity (t ha$^{-1}$) per farm type. Wealthier farmers in Kachia apply increased rates of inorganic fertilizers and hire labour for management activities and these might be the causes for higher productivity on their fields.

Daily energy and protein requirements defined by FAO (FAO 1997) for an average person stand at 2100 Kcal day$^{-1}$ and 95 g day$^{-1}$ respectively. These figures compared to available energy and protein from total food production (Table 21) give an impression of food self sufficiency of farming households at both study sites. In Bunkure Type 1 farmers produce just more than enough food to be self-sufficient. Type 2 farmers produce almost twice as much as they eat whilst Type 3 farmers produce four times of their total food needs. All farmers in Bunkure are hence food self-sufficient despite their large household sizes.

Poor farmers in Kachia are food self-insufficient from the amount of edible produce from their farms. They produce on average 40% of their total annual food needs. For these farmers, casual labour on fields of other farmers is important in order to purchase supplementary food. Type 2 farmers also produce less than their food requirements. What they produce themselves covers 80% of total annual food requirements for their household. Type 2 farmers in Kachia are permanently engaged in off-farm small scale enterprises (SME) hence have an income to purchase food. Type 3 farmers are the only ones in Kachia that produce food exceeding their household food requirements.

Table 22. Amounts and percentages of total crop produce sold at farm level. Sale of cereals, cowpea, and groundnut is the surplus from total food production per farm (Table21).

| | n | Cereals ($t\ farm^{-1}$) | Legumes ($t\ farm^{-1}$) | Ginger ($t\ farm^{-1}$) | Percentage (%) sold | | |
|---|---|---|---|---|---|---|---|
| | | | | | Cereals | Legumes | Ginger |
| *Bunkure* | | | | | | | |
| Type 1 | 3 | 0 | 0.3 | | 0 | 16 | |
| Type 2 | 2 | 2.6 | 1.5[1] | | 33 | 100[1] | |
| Type 3 | 3 | 10.6 | 8.1 | | 62 | 84 | |
| *Kachia* | | | | | | | |
| Type 1 | 2 | 0 | 0 | 0.53 | 0 | 0 | 100 |
| Type 2 | 4 | 0 | 0.36 | 1.94 | 0 | 56 | 100 |
| Type 3 | 5 | 1.2 | 1.80 | 1.80 | 41 | 74 | 100 |

[1]For farm Type 2 in Bunkure local government, all groundnut produce is sold. Cowpea data was unavailable although part will be consumed and the surplus sold.

Total sale of farm produce (Table 22) gives an impression of market orientation of the different farm types in Bunkure and Kachia. Wealthy farmers in Bunkure sell more than half of their cereal produce and almost all of their grain legumes. Type 2 farmers sell their surplus cereals which amounts to circa 2.6 $t\ farm^{-1}$. They also sell all their groundnut produce since they do not depend on this for their food requirements. Cowpea for food and income is inevitably important within farming systems of these farmers but data were unavailable for the crop. Poor farmers in Bunkure sell 16% of their legume produce (groundnut) and the majority is consumed.

The production of ginger in Kachia is an income generation opportunity for all farm types. Poor farmers who do not produce sufficient amounts of cereals have an income from ginger to purchase food amongst other household needs. Type 2 farmers sell part of their legume produce (soybean) alongside ginger. Wealthier farmers sell close to half of their cereal produce and majority of grain legumes. They are market oriented compared to Type 1 and 2 farmers especially regarding legumes.

### 3.10 Partial budget analysis of cropping systems

This section evaluates the economic value of crop productivity. Fertilizer, insecticides, pesticides and labour input are the major costs. Labour is divided into household and hired labour. Household labour entails the opportunity costs for a farmer and his family investing their labour into farming.

In Bunkure, cereals receive the highest investments in inorganic fertilizers, and seed inputs. Cowpea gets the highest costs in terms of chemical insecticides. Groundnut and soybean receive the highest investments in hired labour. Investments in household labour are similar for all crops. Total costs of production are highest in cereals and groundnut followed by soybean and cowpea.

Average fertilizer input in Kachia are higher than in Bunkure. Cereals receive the most of all input costs, hired labour included. The main inputs costs for ginger is inorganic fertilizer when compared to the other crops. Legumes receive less inputs in terms of fertilizer but have high costs for hired labour. This is true for groundnut and soybean but not cowpea. Household labour is highest for legumes that require labour for post-harvest threshing and shelling.

Farmers in Kachia, especially more resource endowed ones, are forced to make use of hired labour due to off-farm activities. Smaller household sizes in general at this site may also be a cause for supplementing household labour with hired labour. Spending on hired labour accounts for 80 and 90% of total costs in crop production in Bunkure and Kachia respectively.

Table 23. Input investment by major crops for both study sites in 1000 Naira $ha^{-1}$.

| | Fertilizer | Chemical input[1] | Seed | Hired labour | HH labour[2] | Total costs[3] |
|---|---|---|---|---|---|---|
| *Bunkure* | | | | | | |
| Cereals | 10 | 2 | 3 | 37 | 93 | 145 |
| Cowpea | 0 | 6 | 0 | 17 | 94 | 117 |
| Groundnut | 1 | 2 | 0 | 49 | 93 | 145 |
| Soybean | 1 | 2 | 0 | 37 | 93 | 133 |
| *Kachia* | | | | | | |
| Cereals | 15 | 4 | 4 | 89 | 84 | 195 |
| Cowpea | 3 | 2 | 0 | 46 | 73 | 124 |
| Groundnut | 2 | 0 | 0 | 77 | 91 | 170 |
| Soybean | 6 | 0 | 0 | 77 | 91 | 174 |
| Ginger | 7 | 2 | 0 | 75 | 84 | 167 |

[1]This combines the costs of both herbicide and insecticide inputs.
[2]Household (HH) labour refers to opportunity costs of labour from household members invested in crop production.
[3]These are the estimated average investment farmers make per hectare every growing season.

A partial economic evaluation of production is performed in this section. The evaluation includes market value of cereal grain, grains of legumes as well as their stover. Especially in the northern Guinea savannah, legume crop residue has high market value and farmers with an excess can sell it on fodder markets in the region. The common legume residue sold is that from groundnut. It has the highest market value of the 3 grain legumes.

Table 24. Partial budget analysis and net benefits of crop production in 1000 Naira $ha^{-1}$ for the study sites.

| | Input costs[1] | | Crop value[1] | | | Net benefits | | |
|---|---|---|---|---|---|---|---|---|
| | Labour excluded | Labour included | Grain | Stover | Total | Ignoring labour costs | Considering labour costs | in USD |
| *Bunkure* | | | | | | | | |
| Cereals | 15 | 145 | 258 | 0 | 258 | 243 | 113 | 692 |
| Cowpea | 6 | 117 | 174 | 59 | 233 | 227 | 116 | 711 |
| Groundnut | 3 | 145 | 168 | 281 | 449 | 446 | 304 | 1865 |
| Soybean | 3 | 133 | 106 | 73 | 179 | 176 | 46 | 284 |
| *Kachia* | | | | | | | | |
| Cereals | 22 | 195 | 106 | 0 | 106 | 84 | -90 | -549 |
| Cowpea | 5 | 124 | 117 | 42 | 159 | 154 | 35 | 215 |
| Groundnut | 1 | 170 | 125 | 113 | 237 | 236 | 68 | 417 |
| Soybean | 6 | 174 | 169 | 65 | 234 | 228 | 60 | 368 |
| Ginger | 8 | 167 | 182 | 0 | 182 | 173 | 14 | 89 |

[1]Detailed information on prices of inputs and produce are given in Appendix 1 (Section 7.1).

From the economic analysis, legumes seem more profitable compared to cereals. In Bunkure the average net benefit from legumes is Naira 155,000 (USD 953) $ha^{-1}$ as against Naira 113,000 (USD 692) $ha^{-1}$ for cereals when costs of labour are taken into consideration. Analysing profitability of individual grain legumes, groundnut gives the highest net benefit to farmers followed by cowpea and soybean. Prices of legumes are similar for all 3 grain legumes between Naira 8000 – 10,000 per 100kg (USD 49-61 per 100 kg), but yields differ giving varying benefits. Average yield of soybean is lower compared to cowpea and groundnut.

In Kachia, the major commercial crops groundnut, soybean, and ginger are the most profitable ones as would be expected. Legumes are more profitable to farmers than ginger. Average net area benefit from all three grain legumes is Naira 54,000 (USD 333) $ha^{-1}$, ginger gives a benefit of Naira 14,000 (USD 89) $ha^{-1}$ and cereal give a negative net returns on costs incurred during cultivation since they are not sold but consumed by the household. In general, net benefits for crops in Bunkure are higher than in Kachia due to increased use of hired labour in Kachia meaning higher production costs. Yields of cereals, cowpea, and groundnut are higher in Bunkure giving higher net returns on a hectare basis.

Economic analysis is perhaps not the most appropriate method of evaluating crop production in the context of subsistence farming in northern Nigeria. The inclusion of household labour opportunity costs helps to give an impression of costs of production but has true value only if farmers can invest their labour elsewhere instead of farming. Food for home consumption is indeed an important objective of crop production and therefore the contribution of crops to food self-sufficiency should ultimately be considered. In Kachia for example, cereals give a negative return but are crucial for food self-sufficiency for poor households. Groundnut and soybean are very lucrative crops and a good source of income for farmers.

### 3.11 Income generation and market access

Table 25. Economic value and net benefits from total crop production at farm level by farm type for both study sites. Values illustrate the monetary value of crops produced taking into consideration the production costs. Total crop produced is used both for household food consumption and the surplus sold for income.

| | | Cereal | | | Legumes | | | Ginger | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Value | Cost[1] | Net benefit | Value | Cost[1] | Net benefit | Value | Cost[1] | Net benefit | Net benefit | In USD |
| *Bunkure* | | | | | | | | | | | | |
| Type 1 | 3 | 87 | 22 | 65 | 176 | 29 | 146 | | | | 211 | 1294 |
| Type 2 | 2 | 324 | 141 | 183 | 120 | 47 | 73 | | | | 256 | 1571 |
| Type 3 | 3 | 680 | 190 | 490 | 864 | 258 | 606 | | | | 1096 | 6724 |
| *Kachia* | | | | | | | | | | | | |
| Type 1 | 2 | 17 | 5 | 12 | 0 | 0.7 | -0.7 | 29 | 0.4 | 29 | 40 | 243 |
| Type 2 | 4 | 33 | 24 | 9 | 55 | 61 | -5 | 107 | 18 | 88 | 92 | 564 |
| Type 3 | 5 | 82 | 65 | 17 | 211 | 80 | 131 | 99 | 13 | 86 | 234 | 1433 |

[1]Costs of production include mineral fertilizer, insecticides, herbicides, and hired labour costs where applicable.

This section deals with income generation at farm level from sale of cereals, legumes, and ginger. The amount of crops sold are based on surplus cereals and legumes after deducting food for home consumption from total food production (Section 3.9). In Kachia, all ginger (100%) produced is sold at the market. Poor farmers in Bunkure utilise all cereal and cowpea produced as food for the household. Part of

groundnut produce is consumed and excess (304 kg $farm^{-1}$) is sold. Type 2 farmers in Bunkure have a cereal surplus of about 33% of total production which is sold. All groundnut produced is also sold. Wealthy farmers in Bunkure sell surplus cereals and majority of their legume produce, both cowpea and groundnut. In Kachia, poor farmers sell only their ginger produce. All food produced is consumed within the household. Type 2 farmers sell all their soybean and ginger produce. No cereals are sold. Type 3 farmers sell surplus cereals, grain legumes, and all of their ginger.
Hired labour costs are a major determinant of farmers' ability to profit from legume production and from crop production as a whole. This is especially true in Kachia where there is increased engagement in off-farm income generating activities hence the need for hired labour. Mainly Type 2 and 3 farmers can make the necessary capital investments during legume cultivation. In general, Type 2 and 3 farmers in Bunkure and Kachia benefit most from the cultivation of grain legumes in terms of income generation from these crops. Importance of grain legumes in farming systems of poor farmers is mainly for food. Between Type 2 and 3 farmers, Type 3 farmers benefit most from grain legumes due to the increased area under legume cultivation.

*Market access*

Farming households market their own produce at the nearest local market. The farmer or a member of the household takes produce to the market for sale. In Bunkure, farmers themselves or their mature sons are responsible for sale of produce. In Kachia, the wife of the farmer usually markets farm produce. Produce is sold locally or to wholesalers who buy for resale in nearby cities.

In Bunkure local government, farmers sell their crops at the Bunkure town market. This is the capital of the local government area and markets days are held weekly on Wednesdays. The market is approximately 10 km absolute distance (15 km by dirt road) from the studied community. The roads are accessible also during the rainy season. Farmers transport produce to the market by means of a motorbike or collective transportation by more farmers using a truck.

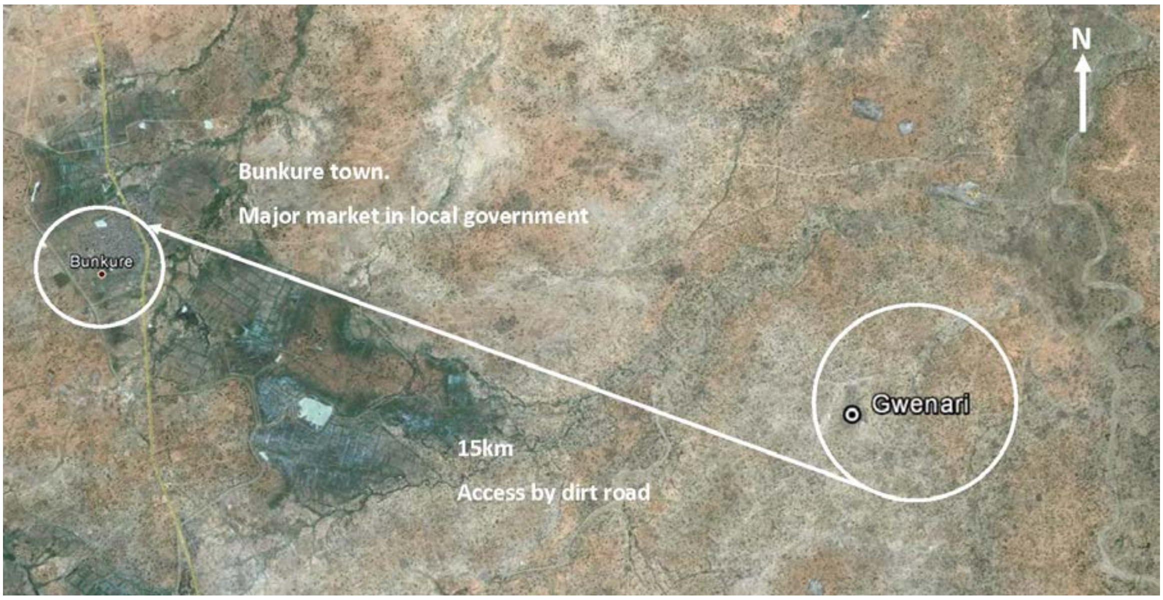


*Figure 8. Distance to major market (km) from studied site in Bunkure local government.*

Kachia has its own weekly market. This market is located 3 km from the study site. Market days are on Friday. Alternatively, farmers can bring their produce to Dagwarga on Wednesdays. This market is 15 km from the studied community. Both markets are accessible by tarred road from the studied community.

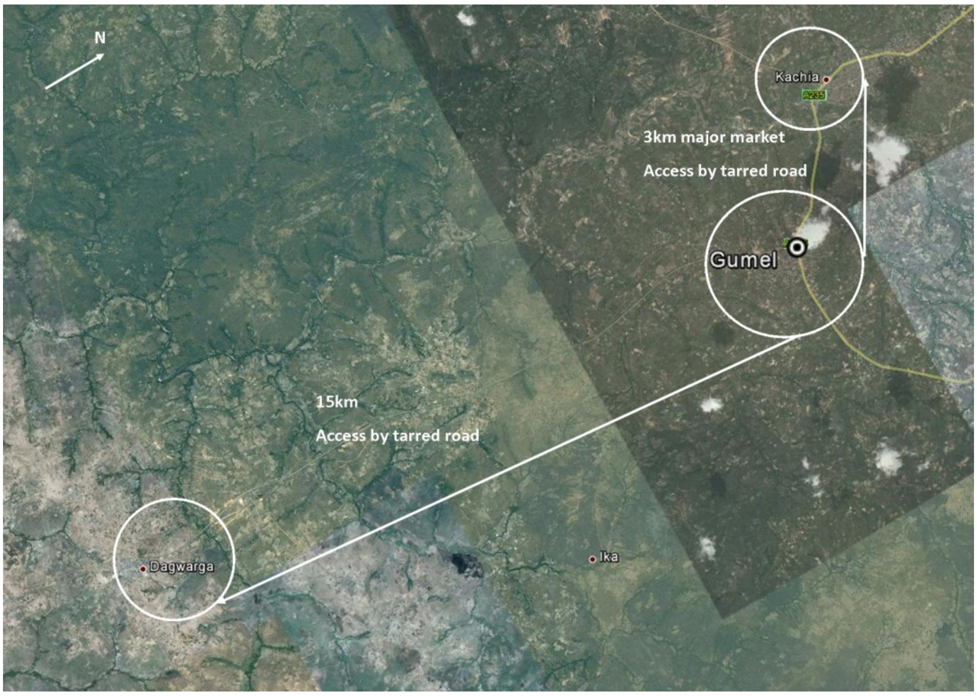


*Figure 9. Distance to major markets (km) from studied site in Kachia local governments*

## 4. Discussion

This chapter evaluates the research methods and discusses the results in the context of the hypotheses set at the beginning of the study. In conclusion, it tries to identify niches in farming systems for grain legumes and their potential to contribute to better soil fertility management and improved crop production in the southern and northern Guinea savannah agro-ecologies of Nigeria.

The study adopted the socio-ecological niche approach (Ojiem, de Ridder et al. 2006) in light of the understanding that a legume technology will only be adopted by smallholders if it fits within the biophysical and socio-economic boundaries of their farming systems. Secondly, the illustration of a farm as a system consisting of various subsystems (Tittonell, Vanlauwe et al. 2005) was used in data collection and analysis.

To perform a detailed intensive study such as this, the sample size of participating farmers is inevitably small. Categorising farmers into a typology enables the capturing of heterogeneity between smallholder farmers who may differ in terms of farming preferences and objectives, resource endowments, types of crops and livestock, etc. This type of study has its strong points in exploring the dynamics of selected farming systems at the given location but its usefulness can be questioned if extrapolated for representativeness of a larger agro-ecological zone. Socio-economic data for Bunkure local government was collected in two village communities within this region and hence broadens the scope of representativeness of the study for the northern Guinea savannah zone of Nigeria. As reported earlier from previous work in the zone by Harris (2001) and Hoffman *et al*. (2001), the farming systems characterised in this report for Bunkure are largely representative for the northern Guinea savannah. For Kachia, the important of role of ginger in cropping systems is unique to this local government and not others in the sub-humid agro-ecology of northern Nigeria (EA Kachia LGA, Personal Communication 2011). Although other crops and management practices within in the entire zone might be similar, the inclusion of ginger in cropping systems of Kachia affects the proportions of land allocation and management practices to other crops in general. Secondly, Gumel (community where data collection took place) is accessible by good motorable roads throughout the year therefore farmers' access to markets for example is higher if compared to other N2Africa communities in the southern Guinea savannah. Kolosok is another community within Kachia LGA which also is accessible by road but the village is distant from the main road whereas Gumel is on the main road. This has implications for farmers in this village in getting their produce to the market in terms of transportation costs.

Although heterogeneity in resource endowments was structured through a farm typology, there is a chance that much poorer households were excluded from this study. Initial selection of participating farmers was done using the N2Africa Baseline Survey data for Nigeria. Possible exclusion of landless or non-farming households could have taken place during the survey. If this was the case during the survey, these groups are by default excluded from this study as well. It is also very likely that for such households, grain legume technologies can hardly be adopted by them specifically due to a lack of crop land and resources to invest in cultivating legumes.

### 4.1 Socio-economic determinants for adoption of legume technologies

The results of this study have shown that cropping systems in northern Nigeria integrate cereals and legumes at field and farm level. Farming systems in the southern Guinea savannah are generally characterised as less intensive due to less population pressure for agricultural land (Singh, Mohan Raj et al. 1997). In this study, we can say that this is evident in the smaller household sizes and presence of natural fallows within cropping systems. On the other hand, cereal-legume intercropping is the typical cropping system of the northern Guinea savannah (Harris 1998; Hoffmann, Gerling et al. 2001). This system has been described as intensive by Harris (2001) typically known for continuous cropping of fields without fallow periods. Increasing population and pressure on agricultural land are reasons for intensification of agriculture in this region.

*Grain legumes and food self-sufficiency*

At both study sites, cereals are the main food crops. Cowpea is an important part of diets in Bunkure but not in Kachia. Cowpea cultivation in Kachia is less than in Bunkure because it is less important for food self-sufficiency. Other lucrative crops, for example ginger and soybean, are cropped instead of cowpea. This preference for different types of grain legumes fits into the socio-cultural niche theory (Ojiem, de Ridder et al. 2006) whereby farmers cultivate some specific grain legumes and not others due to their food habits. Singh et al (2007) also showed the importance of cowpea in the diets of smallholder household in the northern Guinea savannah.

For poor farmers in Bunkure, legumes are crucial for food self-sufficiency. This study was able to show that, Type 1 farmers consume 84% of total grain legume produce. They would not be able to obtain all their food needs from only cereals. For Type 2 farmers at this site, they produce enough cereals to be food self-sufficient and have a surplus of 33% of total production to sell at market. These farmers can also sell their groundnut produce. This study could not show the contribution of cowpea to food self-sufficiency of these farmers, however it is inevitable that they consume a part of their cowpea production. For Type 3 farmers, about 84% of grain legumes produced is sold at the market and not consumed. With their relatively large households they can still sell more than half of their cereals surpluses. These farmers are not subsistence farmers, instead, they are commercially inclined. It can be concluded for Bunkure local government that, increasing resource endowments reduces dependence on grain legumes for food. Wealthier farmers hence benefit from grain legumes as lucrative crops for income generation.

The role of grain legumes as food crops in Kachia is less in comparison to Bunkure. Soybean as a market crop is often grown instead of food legumes cowpea and groundnut. The area cropped to legumes by poor farmers is reduced and substituted for ginger in a lot of cases. For Type 1 and 2 farmers in Kachia, food legumes do not contribute to their food needs. They are partly dependent on own cereal produce for food self-sufficiency and purchase the rest of their food. The grain legume cultivated by these farm types is soybean which is not consumed but rather sold. Hence to these farm types, the benefits derived from grain legume cultivation is cash income. Wealthier farmers who produce all three grain legumes depend partly on cowpea produce for food in order to be self-sufficient. Without this, they could still be able to purchase supplementary food on the market due to off-farm employment. The majority of their legume produce (74%) is sold. It is therefore difficult to say that wealthier farmers grow legumes as a food crop, Instead, and just as Type 1 and 2 farmers in Kachia the cultivation of grain legumes is predominantly targeted for income generation.

*Input use and farm management in grain legume cultivation*

The result of this study showed that in the cultivation of grain legumes in northern Nigeria, input use and management practices differ from dominant cereal crops. Generally, less inputs are used be it organic or inorganic fertilizers. SSP is the major form of inorganic fertilizer applied to legumes. Low availability of manure in Kachia meant this is prioritised for cereals over legumes. Groundnut and soybean require more labour than cereals and only wealthier farmers with off-farm employment can afford to hire labour during the cultivation of legumes.

Despite increased labour demand for groundnut and soybean, poor farmers who cannot afford to hire labour still cultivate these legumes. In Bunkure, larger household sizes provide the needed labour whilst in Kachia, average area cropped to legumes is smaller and can still be managed albeit the smaller household sizes. In general, use of hired labour is more in Kachia than Bunkure. This is first of all due to engagement of more farmers in off-farm employment, either temporary or permanent. Secondly, the land preparation activities in Kachia seem to be more labour demanding because of a more robust vegetation cover and a heavier soil (higher clay content) making tillage activities more tedious. Moreover, farmers in Kachia did not own work bulls or traction animals for tilling the soil.

*Income generation and access to markets*

Grain legumes are important for income generation for farmers in northern Nigeria. Groundnut and soybean are lucrative crops in the northern and southern Guinea savannah respectively. For poor and medium resource endowed farmers in Bunkure, income from groundnuts provides cash for inputs to sustain crop production amongst other needs. Compared to cereals and other legumes, groundnut grain has the highest market value. Additionally, farmers can sell their surplus groundnut residue which earns more income than residues of other crops.

Market oriented farmers reap the most benefits in terms of income from grain legumes. At both study sites, these farmers (Type 3) owned enough land for increased legume coverage and had capital in order to hire labour during the cultivation of legumes. Wealthier farmer in Bunkure for example sold over 8 tonnes of grain legumes per year translating into a total income of Naira 704,000 (USD 4400). Over 60% of their income was generated though sales of cowpea and groundnut. These farmers hence earn a net profit of about Naira 117,000 (USD 717) $ha^{-1}$ $year^{-1}$ which is slightly higher than prevalent levels in the region (Singh and Ajeigbe 2007). Income for Type 2 farmers from crop production comes mainly from the sale of groundnut. This is not a surplus from home consumption but what is purposely grown for sale. Reduced land ownership in comparison to wealthier farmers (Type 3) is a major bottleneck for expansion of legume productivity and increased income possibilities. Future expansion of grain legume area is likely to be hampered by scarce land and hired labour costs contributing to high costs of crop production.

In Kachia, Type 3 farmers also earned a substantial income compared to poorer farmers. Although more than half of their farm incomes are generated from ginger, grain legumes are a more lucrative crop in terms of net profitability. This holds good prospects for soybean for example as it gains popularity and adoption among smallholders in the region.

Additionally, the economic analysis of this study reveal that grain legumes are more profitable than ginger taking fertilizer costs, hired labour and household labour costs into consideration. For poor farmers with limited labour and fertilizer inputs, cultivating grain legumes would seem a better bet on their production resources. For wealthier farmers, this might offer a form of income diversification or security.

The proximity of markets to these study sites means that there is demand and farmers are able to sell their legume produce. Aside local markets, nearby major cities offer further market opportunities for farmers (Franke, Rufino et al. 2011). In the northern Guinea savannah, crop residue markets offer the opportunity for farmers to sell their surplus legume residue.

*Crop-livestock integration at farm level*

On-farm livestock husbandry is an important determinant of farmers' preference for legumes. Legume fodder is used to feed livestock kept at the homestead. These are predominantly goats, sheep, and working bulls. Clear differences were seen between sites on types and varieties of legumes farmers preferred to cultivate. In Bunkure, dual-purpose cowpea variety Dan Bunkure was the common cowpea variety cultivated. Samnut 21 is also a widespread groundnut variety in the region. These two varieties are cultivated for their grain but also for their haulms which farmers feed to livestock. Waste from livestock in form of farmyard manure is important for replenishing plant nutrients. Farmyard manure is the most important form of fertilizers in northern Nigeria with specific reference to the northern Guinea savannah (Harris and Yusuf 2001; Hoffmann, Gerling et al. 2001).

Less livestock in Kachia means farmers have less need for harvesting crop residue from their fields. The production of high haulm yielding legumes is less in Kachia. Instead, farmers prefer legumes with high grain yield potential like soybean. TGx1448-2E is the popular variety of soybean cultivated at Kachia.

Generally, legume crop residue is an important source of fodder to livestock in the sub-humid to semi-arid savannahs of northern Nigeria as they might provide the primary source of protein-wealthy fodder. To prevent severe nutrient depletion from fields due to removal of crop residue to feed livestock, proper management of residues and animal waste products is crucial (Harris 1999). This is important to minimise nutrient losses from residues and manure during storage (Hoffmann, Gerling et al. 2001). The default method of farmyard manure storage at the study sites is to collect it in open heaps close to the homestead. Manure is collected throughout rainy season as well as the dry season till the next cropping before being applied to fields at land preparation. Over this extensive period, considerable loss of nutrients is incurred reducing the quality of the manure drastically (Powell 1986).

For farmers that leave their legume crop residue behind after harvesting the grains, another scenario applies. Larbi *et al* (2002) found that, when 25-50% of legume residue is removed as fodder, good management of the remainder on fields is important to maintain a sound balance of organic carbon, nitrogen, available phosphorus on fields. For example, incorporating residue into the soil instead of them lying on top of the soil. Such insight is important for farmers in Kachia where more than half of the legume residue is left on fields. The unavailability of labour for incorporating residues into the soil is however a likely problem that will determine farmers' ability to carry out this practise (Baijukya, de Ridder et al. 2005).

It is also important to explore the concept of crop-livestock integration (Franke, Berkhout et al. 2010) at farm level since this has an influence on the severity of nutrient losses from the farm. Goats and sheep are fed partly on crop residue at the homestead and partly on open grazing lands. The proportion of time spent at the homestead or on open grazing land has implications for either nutrient export off-farm or import into the farm. At the study sites goats and sheep are kept predominantly on farm so nutrient export in this way is likely to be minimal. One has to ask what the alternatives are to this system of animal husbandry. Farmers in Bunkure for example are very unlikely to sustain an average of 48 sheep and goats solely from their crop residue. The grazing of animals partly off-farm covers for insufficient fodder from crop residues alone but this also represents a trade-off since some manure can be lost during grazing (Tittonell, van Wijk et al. 2009).

Cattle are also important for cropping due to their supply of manure but they are independent from the farm. They only feed on leftover crop stubble at the end of the rainy season. During that process of grazing on stubble, faeces and urine are deposited on farmers' fields but are susceptible to massive losses because they lay on the soil surface for the duration of the dry season. What is incorporated into the soil at land preparation is ultimately of poor quality. Cattle is an important asset in the socio-cultural domain of Bunkure and the northern Guinea savannah at large. They can be sold during times of economic shock and emergency need for cash (Harris and Yusuf 2001; Hoffmann, Gerling et al. 2001; Franke, Berkhout et al. 2010). Open grazing lands are the only options by which farmers can sustain their cattle herds.

## 4.2 Biophysical determinants for adoption of legume technologies

*Rainfall and length of growing period*

The three grain legumes of focus in this study differ very much in terms of agro-ecological suitability. Whereas, cowpea and groundnut are adapted to the semi-arid northern Guinea savannah zone of northern Nigeria, soybean is relatively new to the area. Medium to early maturing soybean varieties suited to savannah regions of northern Nigeria are continually being developed (IITA 2008). Rainfall and duration of the growing period are important factors in soybean cultivation which requires a minimum of 700 mm per annum of rainfall for good yields (Dugje, Omoigui et al. 2009). Rainfall in the northern Guinea savannah especially is unpredictable and rains may last for only 4 months hence only few varieties may be suitable for cultivation in this agro-ecological zone (Akande, Owolade et al. 2007). Previous research in northern Nigeria has shown that the medium maturing soybean variety TGX 1448-2E is the common variety cultivated by farmers in this region (Akande, Owolade et al. 2007; Dugje, Omoigui et al. 2009). This study showed that, soybean land coverage was 1% of total farm land per average farm. On the other hand, farmers in Kachia cropped approximately 8% of the total land to soybean. Comparing Bunkure to Kachia in terms of rainfall per annum and length of growing period, total rainfall in Kachia is 1594 mm and 777 mm in Bunkure. Length of the growing period is 195 and 135 days for Kachia and Bunkure respectively. Biophysical factors hence affect the type of grain legumes cultivated and eventual adoption by farmers.

*Grain legume production and $N_2$ fixation*

Farmers in Bunkure gain the highest contribution of N from $N_2$ fixation on their fields (Table 12). Cowpea fixed a maximum of 104 kg N $ha^{-1}$. Ndfa was 76% on average with considerable variations between fields (44-93%). N fixed by groundnut was lower than cowpea at 65kg N $ha^{-1}$. Ndfa was similar to cowpea at 72% (43-91%). Corresponding grain yields of cowpea and groundnut were 1.7 and 2.1 t $ha^{-1}$ respectively. DM stover yields were 3.5 and 4.3 t $ha^{-1}$.

Yields, BNF, and role of legumes in cropping systems in Kachia are somewhat lower than in Bunkure. At Kachia, an increased number of crops in the cropping system results in less labour, fertilizer and land allocated to grain legumes. Another important factor is that legumes especially cowpea are not core parts of diets. Grain yields of soybean and groundnut were 2.1 and 1.6 t $ha^{-1}$ respectively. Stover DM yields were 2.6 t $ha^{-1}$, whilst soybean yielded 1.8 t $ha^{-1}$. N from Ndfa was 63 (46-76%) and 25% (21-29%) for soybean and groundnut respectively translating into an average of 60 and 28 kg N $ha^{-1}$ fixed on farmers' fields. Also at this site the variations in Ndfa and kg N fixed per hectare were also large between fields.

Number of samples for BNF assessments at both study sites (8 and 6 legumes samples for Bunkure and Kachia respectively) was low and therefore the ability of this study to explore further variations in $N_2$ fixation between fields and study sites is limited. This study acknowledges that more samples should have been taken for BNF assessments.

A review of the literature on legume productivity and BNF in similar agro-ecological zones of Nigeria revealed the following; Franke *et al.* (2004) established average legume grain yields at 0.75 t $ha^{-1}$ in cowpea and 0.9t $ha^{-1}$ for soybean. On-station trials for soybean yielded 1.5 t $ha^{-1}$ (Akande, Owolade et al. 2007). Singh and Ajeigbe (2007) also established grain yields of cowpea at 0.89 t $ha^{-1}$ in the NGS. Several authors have measured BNF in these regions notably Sanginga (2003). In his study cowpea attained between 54-76% (15-201 kg $ha^{-1}$) of its N from fixation. Groundnut fixed 28-81% (11-101 kg $ha^{-1}$) whilst values for soybean ranged between 26-87% (24-188 kg N $ha^{-1}$). Similar results for the contribution of N from BNF have therefore been achieved in this study as has been done in the literature. This is true for all three grain legumes at both study sites except in the case of groundnut at Kachia where lower %Ndfa have been measured. Tables 26 and 27 show an overview of past studies conducted in the Guinea savannah zones compared to results from this study. These studies are conducted on farmers' fields but under varying soil fertility and crop management conditions.

Table 26. Overview of previous studies that measured grain yield of the three legumes compared to yield measured in this study. Data is from researcher managed trials conducted on farmers' fields in northern Nigeria under varying soil and management conditions.

| Grain legume | Grain yield (t $ha^{-1}$) | Reference[1] |
|---|---|---|
| Cowpea | | |
| | 1.74[2] | own data |
| | 1.17[3] | own data |
| | 0.18 | Ajeigbe *et al*. (2010) |
| | 0.39 | Ajeigbe *et al*. (2010) |
| | 1.04 | Singh and Ajeigbe (2007) |
| | 0.72 | Singh and Ajeigbe (2007) |
| | 0.75 | Franke *et al*. (2004) |
| | 0.27 | Carsky *et al*. (1999) |
| Groundnut | | |
| | 2.10[2] | own data |
| | 1.56[3] | own data |
| | 1.31 | Bala *et al*. (2011) |
| | 1.87 | Bala *et al*. (2011) |
| | 1.81 | Kamara *et al*. (2011) |
| | 1.78 | Kamara *et al*. (2011) |
| | 1.86 | Kamara *et al*. (2011) |
| | 2.0 | Kamara *et al*. (2011) |
| | 0.41 | Ajeigbe *et al*. (2010) |
| | 0.90 | Franke *et al*. (2004) |
| Soybean | | |
| | 1.32[2] | own data |
| | 2.11[3] | own data |
| | 1.54 | Laberge *et al*. (2009) |
| | 0.85 | Laberge *et al*. (2009) |
| | 1.53 | Akande et al. (2007) |
| | 1.13 | Sanginga (2003) |
| | 1.35 | Singh *et al*. (2003) |
| | 1.44 | Singh *et al*. (2003) |

[1]Compiled from various studies.
[2]Data from measurements in Bunkure local government.
[3]Data from measurements in Kachia local government.

Table 27. Overview of previous studies estimating biological $N_2$ fixation in northern Nigeria compared to the results of this study.

| Grain legume | Ndfa (%) | $N_2$ fixed (kg N $ha^{-1}$) | Reference[1] |
|---|---|---|---|
| Cowpea | 44 – 93[2] | 47 – 154 | own data |
| | 17 – 21 | 14 - 18 | Yusuf *et al*. (2009) |
| | 36 – 48 | 28 – 40 | Yusuf *et al*. (2009) |
| | 70 | 15 – 31 | Sanginga *et al*. (2000) |
| | 61 – 76 | 47 – 105 | Eaglesham *et al*. (1982) |
| | 54 – 70 | 66 – 120 | Eaglesham *et al*. (1982) |
| Groundnut | 43 – 91[2] | 25 – 143 | own data |
| | 21 – 29[3] | 23 – 31 | own data |
| | 67 – 81 | 11 – 63 | Ganry (1992) |
| | 28 – 52 | 38 – 79 | Badiane and Gueye (1992) |
| Soybean | 46 – 76 [3] | 24 – 89 | own data |
| | 44 – 47 | 36 – 46 | Yusuf *et al*. (2009) |
| | 43 – 46 | 48 – 51 | Yusuf *et al*. (2009) |
| | 26 – 64 | 24 - 168 | Sanginga *et al*. (1997) |
| | 50 – 60 | 65 – 115 | Okereke and Eaglesham (1992) |
| | 84 – 87 | 114 – 188 | Eaglesham *et al*. (1982) |

[1]Data adapted from (Sanginga 2003).
[2]Data from measurements in Bunkure local government.
[3]Data from measurements in Kachia local government.

The wide variations in fixation levels between farmers' fields as we see in the study are very much caused by heterogeneity between farmers management practises (Giller 2001) that might influence the effectiveness of atmospheric $N_2$ fixation. For example, use of inputs such as P fertilizers and the bioavailability of P has a likely influence on nitrogen fixation (Sanginga 2003). Another is timing and frequency of weeding.

An important benefit from legume cultivation is residual N and transfer to subsequent cereal crops. Fujita et al (1992) and Sanginga (1997) amongst others show evidence of beneficial associations of cereal-legume cropping systems in terms of N transfer from legume to cereal albeit little quantification on actual amounts. Wichen et al (2008) have attempted quantifying transfer of fixed nitrogen to millet cultivated in the next cropping season after cowpea. As much as 25% of rhizo-deposited N from fixation was available for uptake by subsequent millet crop. For smallholders in the Guinea savannah zones of northern Nigeria this could be vital source of nutrient cycling for sustainable crop production (Yusuf, Iwuafor et al. 2009).

*Nutrient budgets*

From the calculated farm level nutrient budgets, potassium (K) balances are the most negative of the 3 nutrients in Bunkure and nitrogen (N) is the most negative in Kachia. Despite an average application of about 1.6 t $ha^{-1}$ farmyard manure in Bunkure, nutrient budgets are more severely negative at this site compared to Kachia. Quality of farmyard manure in terms of nutrient concentration is generally low meaning less nutrient available for uptake by crops (Hoffmann, Gerling et al. 2001). A more intensive form of agriculture entailing continuous cropping of cereals without natural fallows takes place in the northern Guinea savannah (Bunkure). That can mean severe nutrient depletion therefore very negative nutrient balances. Harris' (1998) study on nutrient balances in the Kano Close-settled zone depict a more positive level of nutrient balances than shown in this study. In her study, N and P balances were -10kg and 1kg $ha^{-1}$ respectively over a two year period. K balances were on average 45 kg $ha^{-1}$ in sharp contrast to -57 kg $ha^{-1}$ for Bunkure calculated in this study.

On average, N, P, and K balances in Kachia are -16 kg, 2 kg, and -8 kg $ha^{-1}$ respectively and reflect the results found by Harris (1998) except in the case of K. This study showed that farmers in Kachia apply more inorganic fertilizers to the fields during cropping that might lead to less nutrient mining of the soil. Yields of cereals and legumes (except soybean) are also lower compared to those at Bunkure reflecting a reduced level of nutrient removal from the soil. Population pressure on land and the intensity of cropping was also shown to be less at Kachia. All the above factors play a role on the level of nutrient depletion at field and farm level. Moreover, natural fallow practises in Kachia are an alternative for soil fertility management (Yusuf, Iwuafor et al. 2009) and sometimes can result in higher availability of plant nutrients during cropping compared to BNF and residual N benefits from legumes (Franke, Schulz et al. 2004; Adjei-Nsiah, Kuyper et al. 2007).

### 4.3 Potential niches for grain legume technologies

This study observed the role of grain legumes in the farming systems of smallholders in two different agro-ecologies of northern Nigeria. It established that cowpea groundnut, and soybean receive substantial land coverage at farm level. As shown in similar studies by Manenji (2011) and van den Brand (2011), this is not always the case in smallholder farming systems elsewhere in sub-Saharan Africa.

A number of factors are responsible for the important role of legumes in farming systems of northern Nigeria. First and foremost is the importance of cowpea in the diets of a large number of the people. Livestock also plays a key role due to demand for crop residue. Legume residue as fodder for sheep and goats can be equally important as grain yields. Available market for farmers to sell their produce is another important enabling environment for legume cultivation. Especially for groundnut and soybean growers, the existence of a ready market for their produce is an important prerequisite for cultivating grain legumes.

Additionally, Research for Development (R4D) organisations in the agricultural context of northern Nigeria have succeeded in boosting crop production and profitability for smallholder farmers with the development of cropping and crop management technologies. The prominent role of legumes within farming systems is largely through introduction, development, and dissemination of cowpea, groundnut and soybean varieties that are adapted to biophysical as well as socio-economic domain of smallholders in the region. This is a continuing effort of both international and local research organisations and their development partners in northern Nigeria.

Differences between cropping systems in Bunkure and Kachia are clear and this study asks the question if both sites are able to adopt certain aspects of the other's farming practises in order to further enhance benefits from cultivating legumes. For example, can farmers in Kachia increase the area cropped with legumes for higher production of legumes and soil fertility management simultaneously? This would either come at the expense of natural fallows by expanding cultivated land. This could lead to income diversification especially for Type 1 and 2 farmers in Kachia. Such changes will lead to increased labour demand. For poor farmers who can definitely benefit from increasing their grain legume produce, they are constrained by labour and their resource capacity to hire labour. Labour is hence a limiting factor to increased food and income benefits from grain legumes and future work needs to consider labour constraints of farmers and if they are able to benefit from proposed legume technologies since they eventually need to make labour investments.

For farmers in Bunkure, the increased adoption of soybean varieties within their farm systems could have impact on the control of *Striga hermonthica* on cereals fields to minimise yield losses to the parasitic weed. Previous work by Carsky *et al.* (2000) and Kuchinda *et al.* (2003) report on the potential of soybean to reduce *Striga hermonthica* parasitism in subsequent cereal crop through reduction in viable seed bank of the weed. Such technologies hold potential for farmers in Bunkure especially if there are mechanisms put in place to enhance the adoption of early to medium maturing soybean varieties. TGx 1448-2E is one potential variety. Specific testing of such technologies needs to be done however to confirm eventual success. Ultimately, functioning seed systems for distribution and access to good quality seeds by farmers will determine the ability of farmers to adopt the technology (Sanginga, Dashiell et al. 2003).

What this study was unable to uncover is clear differences in resource use and farmer management practises from the constructed typology. This would have enabled the identification of farm type specific niches for legume technologies within farming systems. Nevertheless, two major issues have been identified with regard to grain legumes contributing to soil fertility improvement and sustainable crop production in northern Nigeria. Each aspect is unique per study site.

First of all, proper management of legume residue by farmers that own less livestock and have less need for crop residue as feed. Incorporating legume residue into the soil instead of leaving them on the field for the duration of the dry season would reduce losses in N through volatilisation. Returning legume residue into the soil can account for increased plant nutrient availability in subsequent cropping season and reduce nutrient deficits at field and farm level. Less demand for crop residue by livestock in Kachia also means that future research and promotion of grain legumes should target high grain yielding soybean for example.

Storage and good handling of farmyard manure is important for nutrient cycling in farm systems in Bunkure. Improved storage and management strategies over current farmer practice would eventually result in higher retention of nutrients in the manure. This carries potential for enhanced carbon and nutrient cycling through manure thereby improving overall efficiency of the amount of nutrients transferred to the next crop (Rufino, Tittonell et al. 2007). Due to removal of majority of crop residue to feed livestock, nutrient returns to fields in the form of farmyard manure is one of the few options to recycle nutrients and stem rapid soil nutrient depletion. Farmyard manure, although not analysed in this study is anticipated to be of low quality in Bunkure since current management and storage by farmers is similar to those described in studies carried out in northern Guinea savannah of Nigeria by Hoffman *et al*. (2001).

## 5. Conclusions

From this study, the following conclusions can be drawn:

1. The cultivation of grain legumes is influenced by a number of socio-economic factors such as contribution to food self-sufficiency and availability of markets to sell produce and residue. Resource endowments are also important in order to make inputs investments during cropping. Good yields albeit low input use maintains farmers' ability to cultivate legumes especially cowpea. Large household sizes in northern Nigeria provide labour during cropping and this enables even poor farmers to cultivate grain legumes. However, the income generation opportunities offered by grain legumes in northern Nigeria is open only to wealthier farmers who are able to make the land and labour investments.

2. Types of legumes cultivated are influenced by crop-livestock integration at farm level. Demand for protein wealthy legume residue by goats and sheep is the main driver of farmers' decision making into selecting grain legumes and their varieties with high haulm yielding traits. In the absence of livestock or with less livestock densities, farmers focus on legumes with high grain yielding properties.

3. Biophysical conditions such rainfall and length of the growing period have an influence on the type and variety of grain legumes cultivated. Farmers in the northern Guinea savannah cultivate cowpea and groundnut varieties that are adapted to the unpredictable rainfall season and the short growing period. Their counterparts from the southern Guinea savannah experience a longer rainy season and are able to grow long duration legumes as soybean.

4. Grain legumes can contribute to improved soil fertility mainly through good management of their residue. Thanks to biological $N_2$ fixation by grain legumes, they require less soil N resulting in less depletion of nutrients from the soil. The residues of legumes are wealthy sources of nitrogen and can be recycled into the soil. Farmers with livestock prefer to feed residue to their animals and this represents an export of nutrients from farmers' fields. By returning manure from livestock to fields, farmers can reduce nutrient mining from their soils. However, good management of the manure is needed to ensure good quality and that enough nutrients are returned to fields relative to what was initially exported.

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# 7. Appendix

## 7.1 Socio-economic and biophysical parameters of study sites

Table 28. Costs of inputs and prices[1] of produce given in 1000 Naira per unit used in determining the net benefits of cereals and grain legumes.

| Item | Unit | Unit amount | Unit price | USD equivalent |
|---|---|---|---|---|
| Ginger | kg | 80 | 4.4 | 27 |
| Groundnut | kg | 100 | 8 | 50 |
| Cowpea | kg | 100 | 10 | 63 |
| Maize | kg | 150 | 4.2 | 26 |
| Rice | kg | 120 | 6.8 | 43 |
| Sorghum | kg | 100 | 4 | 25 |
| Soybean | kg | 100 | 8 | 50 |
| Millet | kg | 100 | 3.6 | 23 |
| *Fodder* | | | | |
| Groundnut | kg | 50 | 2.2 | 14 |
| Soybean | kg | 50 | 1.8 | 11 |
| Cowpea | kg | 50 | 0.8 | 5 |
| *Mineral fertilizer* | | | | |
| NPK | kg | 50 | 5.7 | 36 |
| Urea | kg | 50 | 5.7 | 36 |
| SSP | kg | 25 | 3.8 | 24 |
| *Chemical inputs* | | | | |
| Insecticide | L | 1 | 1.2 | 8 |
| Herbicides | L | 1 | 1 | 6 |
| *Animal feed* | | | | |
| Cereal bran | kg | 50 | 1.6 | 10 |
| Groundnut cake | kg | 50 | 1 | 6 |
| Labour (Kano) | $day^{-1}$ | | 0.7 | 4.4 |
| Labour (Kaduna) | $day^{-1}$ | | 0.6 | 3.7 |

[1]Prices of inputs and produce are current prices taken at the time of fieldwork between August-November 2011. Prices are subject to fluctuation during spells of low supply in dry season and relative abundance during harvest periods.

Table 29. Energy and protein content per 100 gram of edible parts of cereal and legume crops.

| Crop | Energy (Kcal) | Protein (g) |
|---|---|---|
| Maize | 345 | 9.4 |
| Sorghum | 345 | 11.0 |
| Millet | 315 | 7.4 |
| Cowpea | 320 | 23 |
| Groundnut | 570 | 23 |
| Soybean | 405 | 34 |

Data retrieved from (FAO 1997)

Table 30. Dry matter (DM) percentage (%) nutrient content of crop parts used in nutrient budget assessments.

| Crop | Grain[1] | | | Stover[1] | | |
|---|---|---|---|---|---|---|
| | N | P | K | N | P | K |
| Sorghum | 0.89 | 0.38 | 0.79 | 0.37 | 0.23 | 0.83 |
| Maize | 1.12 | 0.10 | 0.62 | 0.6 | 0.10 | 1.50 |
| Millet | 1.20 | 0.32 | 0.69 | 0.43 | 0.28 | 1.72 |
| Cowpea | 3.13 | 0.43 | 1.29 | 1.32 | 0.19 | 1.28 |
| Groundnut | 3.48 | 0.68 | 1.06 | 1.19 | 0.14 | 1.32 |
| Soybean | 5.20 | 0.45 | 1.10 | 1.0 | 0.07 | 0.71 |

[1]Nutrient content of crop parts taken from (Harris 1998; Wortmann and Kaizzi 1998)

**7.2 Guidelines and questionnaire detailed farm characterisations in N2Africa**

*Brief introduction*

The detailed farm characterizations aim to establish a baseline situation of some of the project's impact indicators that are not or insufficiently covered through the broad baseline survey. In addition, this activity aims to contribute to an *ex-ante* impact assessment of so-called 'socio-ecological' niches of grain legumes and the associated technologies in African farming systems, i.e. how to target the technologies in order to have a high chance of adoption by farmers. This *ex-ante* study will be conducted among others with the help of modelling techniques, and the detailed farm characterizations will provide necessary input data for the model.

A great deal of the methodologies mentioned in this document has been developed in the AfricaNUANCES project (van der Burg *et al*. 2006) [1]. The emphasis of the currently proposed farm characterization is obviously more on legumes and cropping practices and is less detailed with regard to other aspects of the farm.

*How to select farmers?*

The studies will be conducted on selected case study farms representing different farm types. Ideally, farms are classified based on a typology derived from a broad socio-economic survey, such as the N2Africa baseline survey. Households could then be selected randomly from the households that participated in the baseline survey within each farm type. However, some households may be not be suitable for this activity, as production activities or income sources are not representative for the area or the farm type. Moreover, the farmer should show willingness and ability to participate in this activity. Benefits for the farmer of this exercise are limited; the farmer's contribution is for the general good.

Monitor 3-5 farms per farm type in an area.

*Timing of data collection*

Collecting data for detailed farm characterisations is rather time consuming for both the interviewer and the farmer. To avoid a disturbance of essential farming activities, the timing of data collection is important. Some of the biophysical data, i.e. yield and biological nitrogen fixation, must be measured at specific times towards the end of the growing season, but do not require much of the farmers' time. Much of the other data collection requiring the farmers' participation should be collected at a time when farmers can afford to spend time with the interviewer and are not very busy with the management of the farm. The second half of the growing season, specifically after planting, weeding and fertiliser application to the crop and before preparations for harvest, is usually a period when farmers are less busy. Outside the growing season(s) farmers are also often less busy if they have no off-farm activities, but at this time it may be more difficult to retrieve reliable information on crop management in the previous growing season. National partners will usually be well able to indicate suitable periods for visiting farmers. In those parts of EC Africa that have two growing seasons, visits may have to be conducted in two subsequent seasons.

[1] van der Burg J, P Tittonell, M Rufino, M van Wijk, M Herrero et al., 2006. AfricaNUANCES database – Data collection protocol for detailed farm (sub-) system characterisation. AfricaNUANCES project, Working Document 4, version 7.2.

*The use of the  data collection sheets*

**Data Collection Sheet 1. Village characteristics.** First, collect general village information by interviewing a few key persons in the village (e.g. extension officer and prominent or selected farmers for detailed interviewing). These data need to be collected only once per village.

**Data Collection Sheet 2. First characterisation of farm.** During the first visit to a participating farm, explain the farmers the aims of the N2Africa project and the purpose of this exercise. Confirm his willingness to participate. Record household composition (all those eating from the same pot), cropping history and farmer's perception of legumes.

Draw a map of the farm together with the farmer depicting the farmer's main assets (fields, houses, livestock, fences, grazing lands, etc.). In this manner, the interviewer can get a good impression of how the farm functions. Give a number to each plot.  These field numbers are referred to in the other sections. This farm map serves as a tool to facilitate the collection of other data on crop management, resource and time allocation and input and output flows. This activity is not always a necessity, as the next activities may also give a sufficient overview of the farm layout.

**Data Collection Sheet 3. Livestock.** Collect data on livestock and manure management.

**Data Collection Sheet 4. Field characterisation.** Collect data from *each* field on the farm. Once the farmer has shown the location of all fields, this activity can be done by the data collection team without any direct involvement of the farmer. This is the only data collection activity involving GPS measurements.

Based on the field characterisation, a selection of fields must be made that will be monitored more intensively. If a farmer has 5 fields or less, all fields can be included. If a farmer has more fields, the number of fields for intensive monitoring must be reduced to 3-5. The selection of fields needs to be done carefully! Include fields with legumes and with the main non-legume crop. Also include different field types (e.g. fields close to the homestead and far away, fields at the top of the hill, on the slope and/or in the valley bottom).  The selection of fields should cover the diversity of fields.

**Data Collection Sheet 5. Crop management.** Detailed crop management data is collected in 3-5 selected fields. Collect data on crop management and the use of hired and family labour.

**Data Collection Sheet 6. Income and Expenditures**. Collect data on household income and expenditures on farm-related activities.

**Data Collection Sheet 7. Household nutrition.** Where does the food consumed in the household come from? How food secure Is the household?

**Data Collection Sheet 8. Yield and soil samples.** Follow the protocols on the next pages and use the data collection sheet. Determine yield and collect soil samples in the same selection of fields in which detailed crop management data has been collected (Sheet  5).
Note that an alternative way to collect yield data is by measuring the total (grain) yield of a field after harvest by the farmer. This only works in case the farmer is able to keep yield from different fields separated and stored at the farm until weights are taken.

**Biophysical measurements**

**Yield**

Yield information is obtained through estimations of the farmer (DFC 5. Crop management)) and through measurements by the interviewer, as detailed in this section.

Measure the grain and stover yield of all grain legume crops and the main annual non-legume crop(s) by following the steps below. Use the data entry form given in DFC 7.

Tools needed in the field: measuring tape, cutlass / knife for harvesting, paper bags for transport and storage of plant samples, weighing scale, marker

1. Harvest the crop when it is physiologically mature (usually at the end of the growing season).
2. Harvest the aboveground crop biomass in a field in 3 representative quadrats of about 1 $m^2$ each (depending on the planting arrangement this can be larger or smaller). Also include shed biomass on the ground. Avoid the border rows.
3. Separate the grains from the remaining plant material (stover). Include shed biomass on the ground in the stover sample.
4. Weigh the grains and stover of the harvested biomass from the quadrats.
5. Take a subsample of a few hundred grams of grain and a few hundred grams of stover. Weigh the subsamples.
6. Label the subsamples properly and send them to a laboratory.
7. In the laboratory, dry the subsamples at about $70^0$C for 48 hours or until dry.
8. Determine the dry matter weight of the subsamples.

Note that for some crops, the proposed harvest assessment will not work, for instance when edible parts of the crop are harvested throughout the growing season (e.g. climbing beans) or with perennial crops with a different growing pattern (e.g. bananas). In case of climbing beans, small plots can be fenced off in a field in which the farmer is asked not to harvest anything until yield and BNF determination have taken place.

**Soil samples**

Tools needed in the field: soil auger, rope, bags for storing soil, marker.

1. Take soil samples at a depth of 0-20 cm
2. Take 10-15 subsamples per field, the number depending on the size and heterogeneity of the field. When sampling, follow a ‘V’ or a ‘W’ in the field with the help of a rope.
3. Combine the subsamples to one composite sample per field.
4. Mix the soil of the composite sample well.
5. Take a subsample of 0.5-1.0 kg. The exact weight is not important.
6. Label the subsample of soil properly.
7. Send the subsample of soil to a laboratory.
8. In the laboratory, air-dry the subsample and when dry, store the subsample in a plastic bag or a glass bottle until further analyses

Have the soil analysed for the following traits: pH (H2O), organic C, total N, Plant available P (Olsen), CEC and cations (K, Ca, Mg), soil particle size.