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Fertiliser use and definition of farmer domains for impact-oriented research in the northern Guinea savanna of Nigeria

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Abstract

One of the options to alleviate soil fertility constraints for sustainable agriculture in the savannas of West Africa is to develop soil nutrient management technologies from an adequate supply and feasible share of organic and mineral inputs. This paper makes a diagnosis of farm-level use of organic and inorganic inputs, as a basis for the development of technologies. The results from the diagnosis are then used to develop a framework for characterizing farmers for impact-oriented research on soil nutrient management systems. The survey was carried out with 200 farmers carefully selected in two villages in the northern Guinea savanna of Nigeria. The results showed that more than 90% of farmers in both villages used chemical fertilizers. This is contrary to a general belief that they are not widely applied to food crops by smallholders in African agriculture. However, up to 81% of the fields received less than half of the recommended 120 kg N/ha because of high costs due, probably to removal of subsidies and inefficient marketing systems. Organic inputs such as animal manure were applied in very small quantities (about 8% of the requirements). However there is evidence of integrated use of inorganic fertilizers and organic manure on some (24%) of the fields. The problem to be addressed is that of the production (and efficient utilisation) of organic inputs in the northern Guinea savanna. Nitrogen deficiency is the most limiting soil nutrient in the cereal-dominated systems of study area. On this basis, farmers were classified into two a-priori groups using a threshold of 30 kg N/ha, and multiple quantitative variables were fitted in a discriminant analysis to validate the typology. Results indicated that more than 75% of farmers were well classified into two groups that had the characteristics of the a-priori groups. Two others were atypical and included the remaining 25% of farmers. Thus, there are a total of four groups of farmers referred to as farmer domains in this paper. The two domains with 75% of well-classified individuals are suitable for the selection of farmers with whom to conduct applied research or for development activities because they represent the general patterns in the supply and use of soil nutrients in the study area. Although basic research can be done in the four domains, the two atypical groups are most suited for process-level studies to improve the understanding of factors that make the systems either more efficient or less efficient than the two other farmer domains. In either case, representative farmers were easily identified by their highest probability of belonging to a specific domain from the model results. Multivariate models constitute a good framework to make a typology of, and to select farmers for, participatory research and extrapolation of results in the northern Guinea savanna.

Introduction

Agriculture in countries of the savanna zone in sub-Saharan Africa is in a crisis that is worse than in any other region in the world. The major constraints for agricultural production in this zone are weed infestation, erratic rainfall, and poor soil fertility (Tian et al. 1995). Water and N are the major determinants for food production. For the most commonly grown cereals (maize, sorghum, and rice), the soil must supply approximately 60 kg N in plant available form for each tonne of grain produced (Weber et al. 1992). The problem of nutrient mining is well known. Average annual nutrient loss per hectare for sub-Saharan Africa was 22 kg N, 2.5 kg P, and 15 kg K in 1982–84 and will be 26 kg N, 3 kg P, and 19 kg K in 2000 (Stoorvogel et al. 1993). African soils cannot supply the quantities of nutrients required and levels decline rapidly once cropping commences on new land or on land that had been on fallow. For example, the reduction of fallow from 6 to 2 years has resulted in yield declines from 11 t/ha to less than 2 t/ha for cassava and from 3 t/ha to about 0.7 t/ha for maize in certain areas (Sanginga et al. 1995).

Technological solutions based on the use of chemical fertilizers are available and have been applied in some areas. Bosc and Hanak Freud (1995), for cotton in West and Central Africa, and Heisey and Mwangi (1997) for maize in some countries in Eastern Africa found that use of inorganic fertilizers was widespread among farmers. In general, however, their use remains limited all over Africa because of high costs and inefficient marketing systems (Honlonkou et al. 1999). For example, for 1992 N application was only 7 kg/ha in Africa as compared to about 323 kg/ha in Western Europe (FAO 1993).

An alternative to the use of N fertilizer has been to grow legumes in rotation or in mixed cropping with cereals, as a source of N. The capability of legumes to fix atmospheric N allows them to grow in N-impoverished soils. However, the amount of soil nutrients supplied in those systems solely are not enough to solve crop productivity problems in the African savannas because of exports through harvest (Carsky and Iwuafor 1999). Therefore, sustainable crop production in most of these soils requires continuous addition of inorganic fertilizers and organic inputs for acceptable levels of production. This is the focus of a collaborative research project between the International Institute of Tropical Agriculture (IITA) and the Katholieke Universiteit, Leuven: Balanced Nutrient Management Systems Project for Maize-based Systems in the Moist Savanna and Humid Forest Zone of West Africa, referred to as the BNMS project. Its major goal is to develop and test new agricultural management practices that improve the soil nutrient balance. Main strategies are to promote the use of locally available sources of plant nutrients and maximize their nutrient use efficiency, thereby reducing the need for external and expensive soluble fertilizers, for the moist savanna of West Africa (Vanlauwe et al. 1998). A vital aspect of these strategies is the incorporation of farmers' indigenous knowledge at an early stage of systems development to enhance the adoption of ensuing technology.

The purpose of this research was to develop a procedure for identification of representative farmers for participatory technology development in the northern Guinea savanna, and especially for the BNMS project. The specific objectives were first, to identify current practices in the use of organic and inorganic inputs; second, to use these patterns to classify farmers into homogeneous groups referred to as farmer domains in this paper; and third, to select farmers typical of each farmer domain for participatory technology development.

Various approaches have been used in the past to select farmers for on-farm research. Often researchers got to a village and asked for volunteers who were willing to participate in research, particularly in areas where the farmers were sceptical about the outcome of the proposed research (Smith et al. 1991; Carsky et al. 1998). However, this approach could lead to the selection of an unrepresentative sample and result in bias in research results. This will impinge on the outcome of the research to be extrapolated to a wider area. Another approach is systematic sampling of farmers on the basis of 'one or two clear cut factors' such as different villages, different soil types and gender (Mutsaers et al. 1997). Although this might improve the representativeness of the sample, it will still not be able to capture the broad range of socio-economic differences observed among farmers. As indicated by Ogungbile et al. (1998), large variations exist in agricultural management practices among African farmers so that one or two factors are not sufficient for an unbiased typology and sound selection of representative farmers for on-farm research. There are statistical formulas for the selection of a representative sample from a population on the basis of the variability of a variable of interest and the level of precision required for the sample (Schofield 1996). In agriculture many factors are involved in the process of production so that it is inaccurate to enter one variable only in the statistical formulas for the selection of a representative sample. Moreover, a precondition is the availability of a detailed baseline information on the population before the statistical formulas are applied. This baseline data was not readily available in the study area. Filling in the gap would require that a census be conducted on the population as a whole; this could necessitate many resources that were not available for the present study. In practice, statistical formulas are rarely used in agricultural research for the identification of farmers for participatory technology development. Given the shortcomings of the different approaches outlined above, we developed an alternative approach for farmer selection. It takes into consideration the socio-economic differences among farmers, including differences in resources endowment and commodity production. A multivariate approach, as described in this paper, helps to explore the diversity among farming conditions, combining both multiple qualitative and quantitative variables.

Methodology

Study area

The research was conducted in the northern Guinea savanna ecoregional benchmark area in Nigeria. This is one of six benchmark areas that represent the six ecoregions of the Ecoregional Program for the Humid and Subhumid Tropics of sub-Saharan Africa (EPHTA) (International Institute of Tropical Agriculture (IITA) 1996). Benchmark areas serve as focal points for strategic and diagnostic research and are one of the most important features of an ecoregional program such as EPHTA. Their selection is based on biophysical and socioeconomic features of the ecoregion, on opportunities for successful execution of research, and on ease of extrapolation of research results (Brader 1998).

The northern Guinea savanna covers an area of about 34 million ha in West and Central Africa; it is characterized by a length of growing period between 151–180 days; and its major soils include Luvisols (36%), Vertisols (12.2%), Lithosols (11.3%), Regosols (8.7%) and Ferralsols (8%) (Jagtap 1995). Manyong et al. (1996) found that areas with good access to markets represented more than 50% of the northern Guinea savanna in West Africa (28.5 million ha) probably because major cash crops are grown such as cotton in the francophone countries, groundnut in Senegal, and maize in Nigeria. The northern Guinea savanna benchmark area is a smaller area (6.5% of the zone) in the same ecoregion. This area was chosen because it is large enough to contain the features cited above and gradients of the larger ecoregion and because it offers opportunities for successful research (International Institute of Tropical Agriculture (IITA) 1996). Within the benchmark area, a resource management survey was conducted to identify development patterns that drive the dynamics in the use of natural resources. Then, these patterns were used to cluster the survey villages into homogeneous groups, referred to as resource-use domains. The result was the delineation of four resource-use domains as follows: low resource-use domain (13.8% of survey villages), low to medium (49.2%), medium to high (23.1%), and high (13.8%) (Manyong et al. 1998). Two villages, typical of the two major resource-use gradients of the benchmark area were chosen, Kaya (7°13′E, 11°13′N) and Danayamaka (7°50′E, 11°19′N) (Figure 1). Danayamaka belongs to a low to medium resource-use domain and is dominated by the traditional production enterprises of the northern Guinea savanna, such as sorghum, cowpea, and livestock. Kaya village belongs to a medium to high resource-use domain, is characterized by the development of new enterprises such as maize and soybean, and follows a market-oriented strategy in agricultural production (Manyong et al. 1997).

Temperatures during the rainy period in the study area are 27.3–34.0 °C (maximum) and 18.6–21.6 °C (minimum). The length of growing period is about 150 days occurring between May and October. The mean annual rainfall is between 1200 and 1700 mm and the monthly distribution pattern is similar over the area (Wall 1979).

Soils in the two villages have a sandy loam to clay loam textured topsoil with a pH (H_2O) between 5 and 7 and an organic carbon content ranging between 0.5 and 1.5%. The typical toposequence consists of shal-

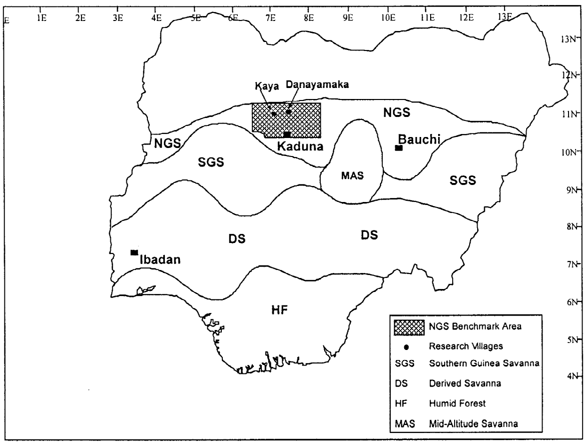

Figure 1. Research villages in the northern Guinea savanna (NGS) benchmark area, Nigeria

low and/or gravely soils (Petric Plinthosols) on the interfluve crests, deep soils (Ferric Luvisols and Ferric Lixisols) on the valley slopes and hydromorphic soils (Gleysols and Fluvisols) on the valley bottoms (Delauré 1998); soils name according to (FAO-ISRI-C-ISSS 1998).

Data collection and analysis

A multi-stage sampling procedure was applied to select 200 farmers for data collection. Firstly, 6 wards were randomly selected, 3 in each village, from the list of all the wards that make up the village. Secondly, the proportions of households from the two villages were determined and used to represent the weight of each village in the final sample. Thirdly, the percentage of households from each ward in a village was calculated and used to determine the size of the sample from that ward. Fourthly, the participating households in the survey from each ward were selected at random from the list of households in that ward. The size of 200 farmers was pre-determined given the fact that resources for the study were limited. Data were gathered on socioeconomic characteristics of respondents, field characteristics, land use patterns, use of organic and inorganic soil amendments (including animal manure, green manure, crop residues etc), membership in farm associations, and farmers' perceptions of the importance of major crops for livelihood and soil fertility.

Descriptive statistics (frequency analysis and means) and analysis of variance were used to analyze the data. A multivariate discriminant analysis was applied to validate an a-prior typology of farmers and select participating farmers for on-farm experimentation and technology targeting.

Discriminant analysis is a method used to investigate the relationship between a known grouping of observations and a vector of explanatory variables on these observations (Marriot 1974). The discrimination is accomplished by combining the set of independent variables into a linear function or index in such a manner that the difference between means of the index for the mutually exclusive categories is maximized (Duncan and Leistritz 1972).

Hence, assuming two or more groups of farmers measured on different socio-economic characteristics and management patterns, a discriminant function for the i^{th} individual in the j^{th} group can be expressed as:

$$Z_{ij} = b_1X_{11} + b_2X_{21} + b_3X_{31} + b_4X_{41} + \cdots + b_pX_{pi}$$

where Z_{ij} – the discriminant score for the individual *i* in the j^{th} group (j = 1, 2, . . . , k; I = 1, 2, . . . , n), X_p – the variable p of an individual *i* (p = 1, 2, . . . , m), b_p – the weight assigned to p^{th} variable as a measure of its contribution to the Z-score of the individual *i* in the j^{th} group.

The empirical model included two a-priori groups of farmers (G1 and G2) and thirteen explanatory variables. The two groups were based on levels of fertilizer application as explained in detail in the next section. Choice of the explanatory variables was on the basis of their hypothesized relation to the level of nutrient use by farmers. Six of these variables correspond to the resource endowments of the system (family size, farm size, livestock units, farming experience, farmer's educational level, farmer's age) and the remaining seven variables reflect the management patterns* of the system (Table 1). Those retained variables showed no strong correlation to each other from a correlation analysis. Data for the typology were complete for only 192 farmers.

Results and discussion

Land-use systems and socioeconomic characteristics

Cereals, principally maize, sorghum, and rice, accounted for over 60% of the cultivated area (Figure 2). Maize was important in Kaya (accounting for 43.3% for farmland) and sorghum was important in Danayamaka (39.2%). Soybean was important in Kaya (25.2%) and less important in Danayamaka (1.3%). In the northern Guinea savanna, maize and soybean are relatively new enterprises in the cropping systems, while sorghum, millet, and cowpea are traditional crops. Root and tuber crops such as sweet potato, cassava, and yam were subsidiary. Cattle and small ruminants constituted essential animal components of the farming systems. On average there were about 1.4 Tropical Livestock Units (TLU) per farmer.

* The variables on management of the farming systems are endogenous and might be of a problem in statistical analyses that are trying to assign causal interpretations to the use of fertilizer. This is not the case in this paper that is aimed at developing a procedure for the selection of farmers from pre-defined groups. The basis for the definition of groups was a hypothesis that fertilizer use drives soil nutrient stocks and agricultural production in the study area. The discriminant analysis was used to validate the typology.

Table 1. Explanatory variables used in the discriminant analysis

Variable	<30 kg N/ha (G1)		≥ 30 kg N/ha (G2)	
	Mean	SD	Mean	SD
Farmer's age (years)	40.27	14.52	36.90	12.59
Farmer's educational level (years)	3.99	3.41	3.12	2.66
Farmer's farming experience (years)	20.73	13.86	18.49	11.71
Farm size (ha)	3.44	2.21	2.72	3.89
Family size (number of persons)	8.76	5.52	8.62	5.91
Livestock units (TLU)	0.95	1.25	1.69	2.34
% maize and soybean residues left in the field	6.85	5.39	7.02	5.82
% area grown to cereals	53.03	27.52	66.48	24.48
% area grown to sorghum	23.97	27.71	12.13	21.85
% area grown to grain legumes	31.37	32.38	19.16	22.14
% area grown to soybean	28.35	30.11	14.35	20.14
Average travel time to fields (min)	18.09	9.97	19.19	18.84
% area under crop mixtures	24.32	34.33	24.73	33.61

TLU = Tropical Livestock Unit

There were more livestock in Danayamaka (53% of farmers own cattle; 3.42 cattle/owner) than in Kaya (16% of farmers, 2.48 cattle/owner).

The average farm size was 3.1 ha for the sample.

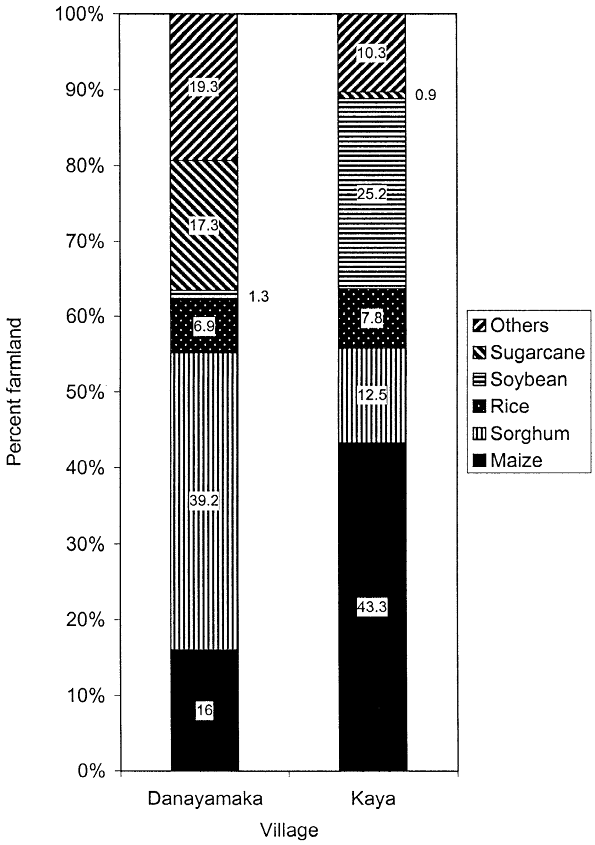

Figure 2. Land-use patterns in research villages of the northern Guinea savanna benchmark area, Nigeria.

About 25% of fields were smaller than 1 ha and only 2% were larger than 10 ha. There was not much difference in farm size between villages (Danayamaka 3.3 ha, and Kaya 3.0 ha) although pressure on land was slightly higher in Kaya (91% of farmers in Kaya do not leave their fields to lie fallow, compared with 87% in Danayamaka). About 80% of fields were sole-cropped according to farmers' estimates. Two major field types, upland (75%) and lowland (25%), were cropped in the study area. Pressure on land is high. Only one farmer out of ten still practices fallows. Fallow types among those who fallow consist essentially of grasses (60%), leguminous cover crops (20%), leguminous shrubs (15%), and non-leguminous shrubs (5%). Duration of fallow is typically short. Average fallow length was 2 years for non-leguminous shrubs and 1 year for other fallow types. Another indication of high pressure on land is on shorter distances of major upland fields from homesteads: only an average of 15.7 minutes in Danayamaka and 21.3 minutes in Kaya. Shifting cultivation as commonly practiced elsewhere in tropical agriculture is no longer possible in the study area. Practices available to farmers for the maintenance of soil fertility in the villages were the use of inorganic fertilizers (97% of farmers), animal manure (29% of farmers), green manure (22% of farmers), and household manure (43% of farmers) (Table 2). The use of leguminous crops for short-term fallow was uncommon.

All respondents were male. In such a Muslim area, male foreigners are not allowed to freely interact with women of the village and there is a common belief that women do not farm. The absence of a female

Table 2. Use of inorganic fertilizers and organic inputs

	Danayamaka	Kaya	All
Inorganic fertilizers			
Users (% farmers)	100	95	97
Organic inputs			
Animal manure (% farmers)	53	17	29
Green manure (% farmers)	29	18	22
Household manure (% farmers)	67	31	43

Table 3. Importance of crop in contributing to soil fertility (% respondents)

	Improving		Degrading	
Crop Rank[a]	1	2	1	2
No. of respondents	87	82	89	86
Maize	3	4	73	7
Sorghum	2	6	12	28
Rice	–	1	2	8
Soybean	40	10	–	2
Groundnut	8	21	–	–
Cowpea	10	16	–	–

[a]1 = most important; 2 = second most important

enumerator among the research prevented the validation or rejection of this belief. Age of respondents ranged between 13 and 82 years with an average of 38 years. Average farming experience was 19 years. Literacy level (% respondents with primary education) was higher in Kaya (46%) than in Danayamaka (35%). Land was acquired mainly by inheritance (65% of fields). Other modes of land acquisition were leasing (11% of fields), gift (9.7%), buying (7.5%), and renting (6.2%). Acquisition of land by inheritance was higher in Danayamaka (77% of fields) than in Kaya (57%). The land market (i.e. buying and renting) was more developed in Kaya (17.6% of fields) than in Danayamaka (7.6%).

Farmers' perceptions of crop contribution to soil fertility

Farmers' perceptions of crop importance in improving or depleting soil fertility were investigated to get a first hand indication on farmers' potential to accept new technologies that could enhance the soil nutrient stocks. Cereals, particularly maize and sorghum, were regarded as depleting soil nutrients while legumes (soybean, groundnut, and cowpea in that order) were regarded as not depleting soil fertility. Some farmers were aware that legumes, in particular soybean improves soil fertility (Table 3). These results indicate that farmers already positively perceived the role a legume could play in the enhancement of soil fertility as compared to cereals.

Use of inorganic fertilizers

The use of chemical fertilizers is widespread in the study area (95% of farmers in Kaya and 100% in Danayamaka) (Table 2), contrary to a general belief that their use is limited in African agriculture (Mokwunye and Hammond 1992). Farmers in the two villages applied NPK (63.6% of fields), urea (27.4%), and SSP (5.3%) (Table 4). Three brands of NPK, one brand of urea and one brand of SSP were identified by farmers, using the local names, which attests further to the farmers' familiarity with inorganic fertilizers. Past agricultural policies had played a major role in the popularity of chemical fertilizers in the northern Guinea savanna, such as fertilizer subsidies (usually above 80%) and good extension services (Smith et al. 1994). Also, the release of fertilizer-responsive and high yielding improved maize varieties in the 1970s promoted the utilization of chemical fertilizers (Smith et al. 1997)

With the removal of subsidies and government withdrawal from the distribution systems in the mid 1980s (Kwanashie et al. 1997), fertilizer use dropped substantially. Although increases in prices have had little effect in reducing the popularity of fertilizer among farmers (Table 2), the high costs appear to have had some effect on the level of fertilizer applied. About 80% of fields in the two villages received less than half of the 120 kg N/ha recommended for cereals in the study area. However, the rates of fertilizer application varied widely among farmers, shown by the high standard deviation around the means in each village (Table 4).

Use of organic inputs

Farmers in the study area were found to apply three types of organic manure: animal manure, green manure, and household refuse to their fields. About 30% of farmers applied animal manure (Table 2). This percentage was higher in Danayamaka (53%) as a result of the presence of more livestock. The use of other organic inputs was 22% of farmers for green manure and 43% of farmers for household refuse. However, the quantities applied are small. For example, only 19% of fields received household refuse (23% in Danayamaka and 15% in Kaya). Use of organic manure was lower in Kaya village than in

Table 4. Fertilizer types and application rates

Fertilizer type	Danayamaka (n = 384)	Kaya (n = 411)	Both villages (n = 795)
(% of fields)			
NPK (15:15:15)	24.0	14.8	19.2
NPK (20:10:10)	7.3	18.2	13.0
NPK (27:13:13)	28.7	34.1	31.4
Urea (46:0:0)	37.5	18.0	27.4
SSP	7.6	3.2	5.3
Rates (Kg N/ha)			
Mean	43.41	38.30	40.06
SD	30.26	31.75	31.26
% of fields with ≤ 60 kg N/ha	78.8	81.8	80.7

n = number of fields

Danayamaka. Farmers used different combinations of organic and inorganic inputs (Table 5). Sole application of inorganic fertilizers was the most common practice in the survey villages (54.6% of fields).

Experimental evidence from the literature indicates that combining organic and inorganic materials results in higher yields than application of inorganic fertilizers alone (Raju 1979; Meelu 1981; Iwuafor et al. 2000). Results from the present research indicated that the use of organic manure (animal and household) was still very limited in the study area. Only 28% of fields received organic manure. Of these, 31.5% received animal manure, 38.3% received household refuse, and 30.2% received a mixture of animal and household manure. A major hindrance to the use of organic manure is lack of availability. If we assume that 450 kg manure/TLU/year can be collected (Fernández-Rivera et al. 1995), farmers can produce on average only 124.3 kg manure/ha/year for Group 1 and 279.6 kg/ha/year for Group 2 from their own animals (Table 1). These averages represent about 5% for Group 1 and 11% for Group 2 of 3000 and 7000 kg (average of 5000 kg) of manure that are needed per hectare every two years to replenish the nutrients taken up through grain and stover removal (Williams et al. 1995). Therefore the problem to be addressed is that of the production (and efficient utilisation) of organic inputs in the northern Guinea savanna.

Another difficulty is associated with transporting bulky and wet organic manure. Farmers would preferably apply small quantities of manure to fields close to homesteads.

Typology of farmers

Negative balances on soil nutrients were recorded in farmers' fields in the northern Guinea savanna for both Nitrogen (average of 36 kg N/ha with values ranging up to 80 kg N/ha) and Phosphorus (average of 11 kg P/ha with values ranging up to 23 kg P/ha) (Diels et al. 1999). Application of a commercial fertilizer such as NPK (15-15-15), commonly found in the study area would require only small quantities up to 100 kg/ha to take off the negative balance for P. However, the same quantity of the same commercial fertilizer would not balance up the N depletion. Moreover, results from on-farm trials in maize fields showed a higher response to N application than to P application. Responses to the other elements such as K, Ca, and micronutrients were not significant (Diels et al. 1999). Therefore, Nitrogen is the most limiting nutrient for the dominant cereals of the study area.

Table 5. Fertilizer management practices (% fields, n = 795)

	No manure	Animal manure	Household manure	Animal and household manure
No fertilizer	17.9	1.3	1.9	0.9
SSP	1.3	0.3	0	0.1
NPK	35.7	3.4	5.2	3.8
Urea	5.3	2.4	2.4	1.3
NPK+SSP	0.4	0.3	0.1	0.3
Urea+SSP	0.6	0.3	0.1	0.4
NPK+Urea	10.7	0.8	0.9	1.1
NPK+Urea+SSP	0.6	0	0.1	0.5
Total	72.5	8.8	10.7	8.4

Since organic inputs are applied only in small quantities, we hypothesized that inorganic fertilizers are the main source of soil nutrients and drive agricultural production in the northern Guinea savanna. On the basis of this hypothesis, two groups of farmers were created: ‘‘no N-users’’ referred to as Group 1 (G1) and ‘‘N-users’’ referred to as Group 2 (G2). G1 include those farmers who apply less than one quarter of the recommended dose of 120 kg N/ha for cereals, and otherwise for G2. Using the commonly sold compound commercial fertilizer (15-15-15), the application of at least 25% of the recommended dose is required to expect appreciable gains on yields, which are brought about by the synergestic effect between P and N in the cereal-based systems of the study area, as shown above for the negative balances of N and P. Several studies (Carsky and Iwuafor 1999) have also shown slight response of maize to an application of at least 30 kg N/ha, depending on the soil conditions. Farmers who apply less than 30 kg N/ha would naturally get higher yields than those who do not use fertilizer at all would. Despite this advantage, they were grouped in G1 in the present study on the hypothesis that benefits derived from such a small quantity of inputs are negligible. The N rate also reflects the amount of money a farmer can, or is willing, to spend on external inputs. It is hypothesized that the two farmer groups might need different technologies or might show different adoption patterns. The typology of farmers was conducted for all the farmers regardless of their village of origin because the objective of the analysis was the selection of farmers who represent gradients in the use of soil nutrients for participatory technology development.

The analysis led to the identification of four groups, referred to as farmer domains (D1 to D4) (Table 6). D1 is typical of the original G1 and D2 is typical of G2. A large majority of farmers (75.5%) were well classified in D1 and D2 (Table 6). This result validates the a-priori typology based on the classes of input application since less than one-quarter of farmers were mis-classified in D3 and D4. To ensure that 25% of the recommended dose of N application was an adequate threshold for the a-priori typology of farmers, other thresholds of N were tested: 12.5%, 37.5%, 50%, 62.5%, 75% and 87.5% of the recommended dose of 120 kg N/ha. The threshold of 100% was not included because the resulting size of the group above that threshold was only 4.2% of the sample, which is too small for the analysis. In addition, two other approaches for an a-priori typology of farmers were also tested: a modal distribution of fertilizer use, with a group below and another above the mode of 37.8 kg N/ha; and a village distribution of farmers, with one group for Kaya and another group for Danayamaka. The results from these alternative thresholds and approaches were compared to those from the threshold of 30 kg N/ha, which represent 25% of the recommended dose of 120 kg N/ha in (Figure 3). The result on the percentage of well classified individuals, the decision criterion to validate a good discrimination among groups (Romeder 1973; Gérard 1es Universitaires St-Louis1980; Manyong et al. 1998), was used for the purpose of comparisons. The village approach gave the best results (87% of well classified individuals), which confirms previous findings that the two villages belong to two contrasting resource-use domains. However, the result from such a village-based typology does not serve our purpose, which is to identify representative farmers for participatory technology development within a village. The results were similar (75.5%) for the typology based on our hypothesis of 30 kg N/ha from on-farm trials and that based on the modal distribution of 37.8 kg N/ha fertilizer use. The remaining thresholds of N rate gave lower percentages of well classified individuals. The above results from N rates are not sensitive to the cutoff chosen for the typology, which attests to the fact that N/ha is a valid criterion for the discrimination of groups. However, the level of 30 kg N/ha is the best among all the N thresholds for an initial typology of farmers within a village in the study area.

A subset of six variables at $P = 0.05$ and two variables at $P = 0.10$ out of the thirteen initial explanatory variables in the empirical model contributed significantly to the discrimination of the groups. These variables include percentage of area cultivated to soybean (7.27% of the variance on the discriminant function), percentage of area cultivated to sorghum (6.73%), farm size (4.52%), percentage of area cultivated to cereals (3.03%), farmers’ age (2.63%), size of livestock herd (2.53%), percentage of area cultivated to legumes (1.99%), and farmers’ educational level (1.88%). Both types of variables describing the resource endowments and the management of farm resources contributed to the typology. This result on significant variables for the discrimination of groups has implications for the typology of farmers. While our hypothesis-based threshold of 30 kg N/ha was confirmed as a good criterion for an initial grouping of farmers, a sound typology of farmers in the northern

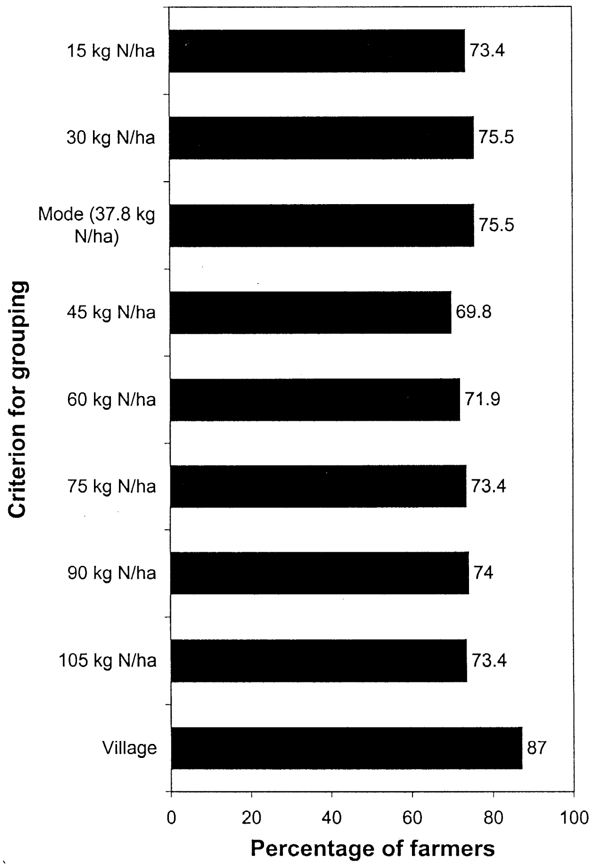

Figure 3. Percentage of well-classified individuals from alternative approaches used for an a-prior typology of farmers in the northern Guinea savanna benchmark area, Nigeria

Guinea savanna would require the inclusion into the analysis of variables on the resource endowments and on the management of the systems. The variables ''age'' and ''farming experience'' were highly correlated (r = 0.81 at $P = 0.0001$). And so for the variables ''percentage of area cultivated to soybean'' and ''percentage of area cultivated to legumes'' (r = 0.91 at $P = 0.0001$). The removal of one variable out of the two highly correlated variables resulted in a small decrease on the percentage of well classified individuals and the number of significant variables for the

Table 6. Definition of farmer domains

	Kg N/ha : Predicted		
Kg N/ha: Actual	< 30	≥30	Total
< 30 (G1)	61 (D1)	20 (D3)	81
≥ 30 (G2)	27 (D4)	84 (D2)	111
% well classified	75.3	75.7	75.5

discrimination. However, the above implications for a good typology of farmers were not affected at all by the changes. Therefore they remained relevant for the northern Guinea savanna.

The characteristics of the four farmer domains are shown in Table 7. Farmers in D2 are more intensified (e.g. higher N rates, smaller farm size, more livestock per unit of land, higher area grown to cereals, higher cereals yields, but less grain legumes) than those in D1. Farmers in D3 practice a low intensity system using very low fertilizer rates, but with a higher percentage of land cultivated to cereals. Farmers in D4 have a more intensified system, using low to moderate N rates, but having more land than in any other farmer domain. D1 and D3 originated from G1, likewise D2 and D4 from G2. However, the comparison between the characteristics of the original groups (Table 1) and those of the four domains (Table 7) indicates that D1 is very close to G1, while D3 is not for most of the variables (farm size, TLU, % of area grown to cereals, % of area grown to soybean, ...) So, for D2 that is very close to G2 while D4 is not. This result explains why D1 is typical of the original G1 and D2 is typical of G2. Therefore, another important implication from the typology is on the choice of farmers for either basic research (process studies) or applied research and development activities. If the objective of research is for systems development and technology targeting (i.e. applied research or development), farmer domains D1 and D2 would be favorably considered because they represent the majority of farmers in the area and are typical of the gradients identified in the most limiting factor of production, the resource endowments, and the management of the system. If the objective of research is to improve our understanding on processes leading to differences between groups, all the farmer domains are indicated for such process studies. However, farmers in D3 and D4 deserve a special consideration for process studies because they are atypical of their original groups. A ratio of kg cereals produced to kg N applied, a proxy of a measure for the efficiency of a system, was calculated to show how atypical farmer domains D3 and D4 are compared to D1 and D2 (Figure 4). Farmers in D3 achieved 124% of the ratio of farmers in D1. Farmers in D4 achieved only 88% of the ratio of their counterparts in D2. Undoubtedly farmer domains D3 and D4 are atypical: the former is the more efficient and the latter is the least efficient in the study area. The need to understand and explain the factors behind the differences between the two ex-

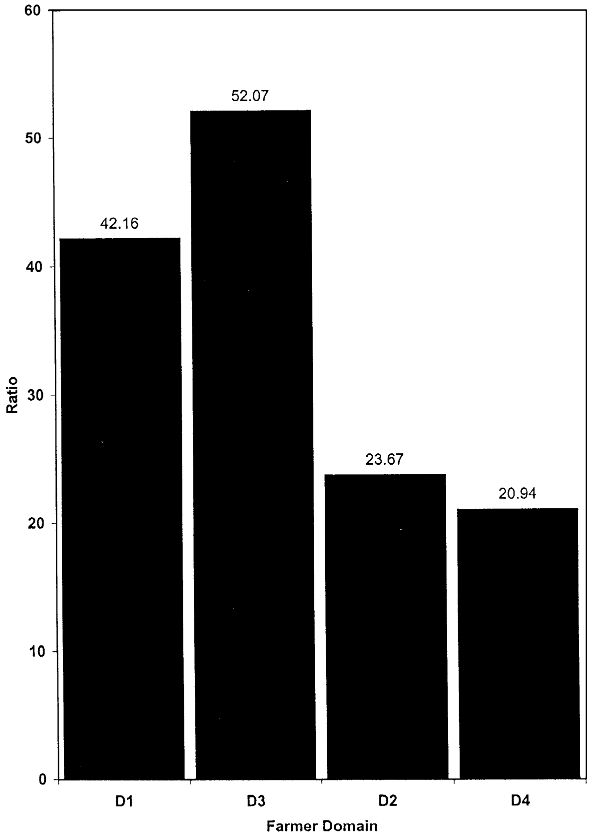

Figure 4. Ratio of average cereal yield (kg dry matter/ha) to fertilizer N use (kg N/ha) by farmer domain in the northern Guinea savanna benchmark area, Nigeria

treme farmer domains would justify process-level studies or basic research in the various components of their cropping systems.

Table 8. Number of farmers in each farmer domain based on posterior probability

Probability	Farmer domain D1	D2	D3	D4	Total
> 0.85	17	22	2	2	43
0.75–0.85	19	21	4	7	51
0.50–0.74	25	41	14	18	98
Total	61	84	20	27	192

Selection of participating farmers

Another interesting output from a model on discriminant analysis using the parametric method (as it is the case in this paper) is the posterior probability of each individual to be classified into a group. The posterior probability of an individual *i* belonging to a group *j* is calculated using the generalized squared distance from a *P*-dimensional vector containing the quantitative variables of *i* to group *j*(SAS Institute, Inc 1989). The individual *i* will be allocated to a group *j* whenever his posterior probability *Pi* to be classified within that group is more than the ratio of 100 to the total number of groups. The higher the probability the more the individual is characteristic of the group (Manyong et al. 1998). Results from (Table 8) indicate that farmers with a posterior probability above 85% in a farmer domain should be selected first because they constitute the most representative farmers for that domain. If more farmers are needed, or if some farmers with higher probability are not willing to participate in experiments, then subsequent lower posterior probability farmers are contacted, and so on until the desired number of participating farmers is reached.

Table 7. Characteristics of farmer domains

Variable	Farmer domain D1	D2	D3	D4
N rate (kg/ha)	14.16[a]	60.08[b]	13.77[a]	56.30[b]
Farm size (ha)	3.51[a]	2.22[b]	3.22[a]	4.27[a]
Livestock (TLU)	0.58[a]	1.81[b]	2.08[b]	1.31[ab]
Travel time to fields (min)	18.36[a]	19.44[a]	17.26[a]	18.41[a]
% area grown to soybean	33.04[a]	9.97[b]	14.06[b]	27.98[a]
% area grown to sorghum	27.20[a]	16.20[b]	14.12[b]	24.14[b]
% area grown to cereals	48.97[a]	70.67[b]	65.44[ab]	53.47[a]
% area grown to grain legumes	35.87[a]	16.22[b]	17.67[ab]	28.31[a]
Maize yield (kg/ha)	337[a]	1040[c]	533[a]	768[b]
Sorghum yield (kg/ha)	260[a]	382[b]	184[a]	411[b]
Soybean yield (kg/ha)	391[a]	248[a]	254[a]	405[a]

Means with same letters are not significantly different at 5% (row-wise)
TLU = Tropical Livestock Unit

This framework for the definition of farmer domains and selection of farmers is being implemented in the northern Guinea savanna benchmark area for farmer participatory research on management of biological N fixation, crop livestock integration, and cereal—grain legume rotation trials.

Summary and conclusions

This paper reports development of a procedure to incorporate socioeconomic differences and variability in nutrient management systems in the selection of farmers for participatory research and technology development. Due attention was given to the current nutrient management patterns among surveyed farmers. Results from this paper show that inorganic fertilizers are the most popular source of soil nutrients to enhance soil fertility, although application rates are much lower than the recommended rates, probably because of the removal of subsidies. There is evidence of an integrated use of organic manure and inorganic fertilizers on some of the fields. However, the use of animal manure and green manure is relatively small compared to inorganic fertilizers. The production of organic inputs is a big problem to address in the northern Guinea savanna. Although the system is cereal-dominated, farmers had begun to perceive the role of legumes in the enhancement of soil fertility. N supply is the most limiting factor in crop production in the study area. It is on this basis that farmers were classified into two groups using the level of nutrients applied. Results from the discriminant analysis validated the typology and indicated that the N rate application in the cereal-based systems of northern Guinea savanna is a suitable criterion to make an initial grouping of farmers. However, a sound typology would require additional factors on resource endowments and management of the systems in order to fine-tune the initial grouping and select farmers for participatory research.

The results on the typology of farmers have implications for the type of research to be practiced. If the objective of research is to develop improved nutrient management systems with farmers or the targeting of research findings (i.e. applied research or development), then the broad patterns of nutrient management practices represented by farmers in D1 and D2 would be most suitable for such experimentation. However, if the objective of research is to improve the understanding of sources of variability among farmers in the same environment (basic research or process studies), it is appropriate to consider all the four farmer domains. Farmers in D3 and D4 are especially most suitable for process studies. In all cases, selection of participating farmers should begin with those with the highest probability of belonging to a farmer domain, as they constitute the most representative farmers within that group. Multivariate models as shown in this paper constitute a good framework to make a sound typology of complex systems and select representative farmers for participatory research in the northern Guinea savanna.

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