Analysis of constraints to agricultural production in the Sudan Savanna Zone of Nigeria using multi-scale characterization.

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Abstract

A multi-scale characterization approach was used to identify the major constraints to agricultural production and to characterize the major production systems in the Sudan Savanna Zone of northern Nigeria. Relative emphasis was placed on the household-level characterization to have a better understanding of the land use system, farmers' constraints and opportunities, so as to better target agricultural technologies and interventions in this vast agro-ecological zone. Large variations exist in agricultural management practices among villages and households in terms of access to resources, such as labour, fertilizers, livestock, farm equipment, and land. Intensive and extensive farming practices co-exist within the same villages and households. Results were also used to identify benchmark sites.

Résumé

Une approche de caractérisation multi-échelle a été utilisée pour identifier les principales contraintes à la production agricole et caracteriser les systemes de production dans la zone savanne soudanienne du nord-Nigéria. L'accent a été mis sur la caractérisation au niveau des ménages pour mieux comprendre les systèmes d'utilisation des terres, les contraintes et possibilités des paysans afin de mieux cibler les technologies et les interventions pour cette vaste zone agro-écologique. Il y a des grandes différences dans les pratiques de gestion agricole entre les villages et les exploitations, en termes d'acces aux ressources comme la main-d'oeuvre, les engrais, le bétail, les équipements agricoles, et la terre. Des pratiques de culture intensive et extensive co-existent au sein des mêmes villages et ménages. Les résultats ont également permis d'identifier des sites de référence.

***Keywords*:**
Multi-scale characterization approach, Sudan Savanna Zone, Nigeria, benchmark sites, participatory research

***Mots clés*:**
approche de caractérisation multi-échelle; zone de la savanna soudanienne; Nigéria; sites de référence; recherche participative

Introduction

Agricultural potential in Nigeria is unlimited with opportunities for agricultural development spanning five agro-ecological zones, each with its unique characteristics. The Sudan Savanna agro-ecological zone alone, extending between latitudes 9° 30' and 12° 31' N and longitudes 4° to 14° 30' E, occupies about 22.8 million hectares (Manyong *et al*., 1995). Its rainfall is unimodal and ranges in space and in time between 600 and 1000 mm per annum. The zone is characterized by a length of growing period of about 100-150 days and opportunities exist for the cultivation of rainfed cereals, groundnuts, cowpea, cotton, pigeonpea, irrigated rice and wheat, and vegetables. The zone includes six states, each having its own agricultural development project. Cropping systems are based on millet and sorghum, but with the increasing population densities, and the recent reduction in fertilizer subsidies, the quest for alternative, but yet productive and sustainable production systems becomes more important.

As with other agro-ecological zones, there is a large diversity in the Sudan Savanna zone in terms of biophysical (climate, land form, hydrology, etc.) and socio-economic (land and labour resources, marketing and tenure practices, etc.) parameters. As a result, agricultural technologies developed to address problems across agro-ecological zones have been of limited value and have not been adopted to any appreciable extent. Since the land use systems and production strategies adopted by farmers depend on the interactions between the biophysical and socio-economic resources available to them, it is only through characterization and diagnosis at different levels of scale that a better understanding of the environment in which farmers operate and of the constraints can be obtained for accurate targeting of improved technologies and policies. Since research institutes do not have the financial nor the human capacity to investigate all combinations, a sound selection therefore needs to be made that is representative of a larger area, i.e. the benchmark sites.

The objectives of this study were to carry out a multi-scale characterization in Nigeria across states to identify constraints to production, and subsequently to select benchmark sites within the Sudan Savanna zone for further technology development and testing with farmers so as to facilitate extension of results to similar areas.

Materials and methods

A multi-scale characterization method was used (cf. Andriesse *et al.*, 1994; Van Duivenbooden, 1997) with administrative units as unit of analysis. It telescopes down from State, via Local Government Area (LGA) and village to households. The states of Kano, Jigawa and Katsina were selected as representative of the Sudan Savanna zone in terms of rainfall amount and distribution, and vegetation. The study was carried out in three LGAs selected in each state based on annual rainfall within the last five years (longer periods were not available), representativity of the production systems and geographical position within the states. In each LGA, a survey was made in villages on a transect with a north-south axis. The villages (Figure 1) were selected on the basis of annual rainfall (1991-1995), geographical position in the state, accessibility, and representativity of main production systems and ethnic groups. Detailed characterization was carried out in one village selected in each LGA. In those villages, a Participatory Rural Appraisal survey was conducted in September and October 1996, and activities of households (selected on the basis of interviews) were monitored. Additional interviews with the household heads were held to determine their farming practices and resource endowments.

Figure 1.

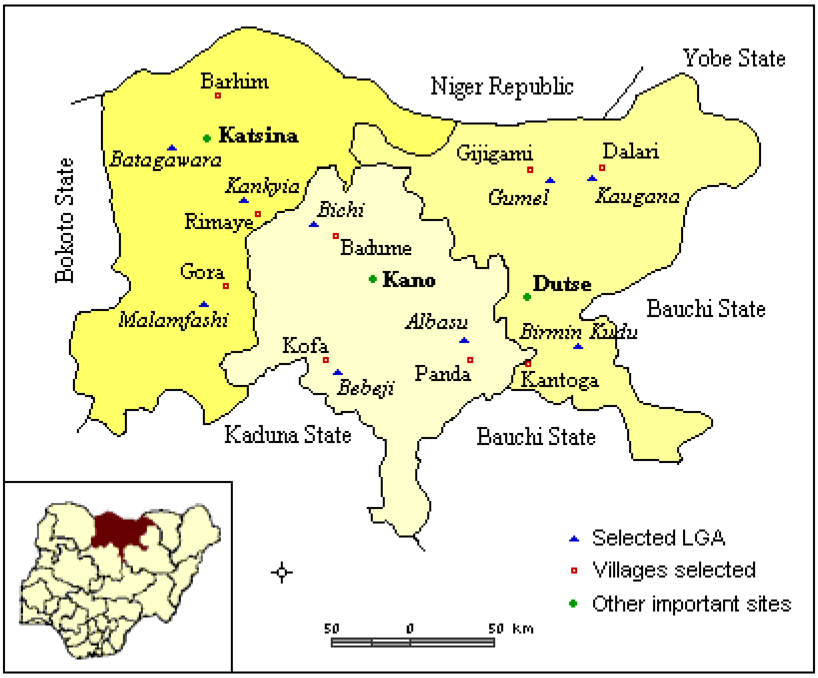

Figure 1. Location of the studied villages in Sudan Savanna zone of Nigeria.
Figure 1. La position des villages étudiés dans la zone soudanienne du Nigéria.

Although the Sudan Savanna Zone is often subdivided in Nigeria into the wet and the dry sub-zone, in this study, three zones were distinguished on the basis of average annual rainfall:

i. the southern zone from 11° 30' to 11° 55' with 951 mm;
ii. the middle zone from 12° 12' to 12° 19' with 777 mm; and
iii. the northern zone from 12° 34' to 12° 58' with 512 mm (Table 1).

Table 1. Location and selected bio-physical details of the nine villages in Nigeria.
Tableau 1. La position et quelques details bio-physiques des neuf villages au Nigéria.

State	No. LGAs	Selected LGA	Village Name	sub-zone	Village coordinates		Main soil type	Average rainfall (mm)
					Lat.	Long.		
Kano	34	Bebeji	Kofa	South	11°34'	8°17'	Loamy	957
		Albasu	Panda	South	11°31'	9°04'	Loamy	787
		Bichi	Badume	Middle	12°12'	8°19'	Sandy	675
Jigawa	21	B/Kudu	Kantoga	South	11°30'	9°23'	Sandy loam	1011
		Kaugama	Dalari	North	12°36'	9°48'	Sandy	462
		Gumel	Gijigami	North	12°34'	9°25'	Sandy	612
Katsina	21	Malumfashi	Gora	South	11°55'	7°43'	Loamy	1050
		Kankyia	Rimaye	Middle	12°19'	7°54'	Loamy	879
		Batagarawa	Barhim	North	12°58'	7°41'	Sandy	461

Results and discussion

Rainfall

At the scale of agro-ecological zone, the mean annual rainfall at the sites for the 1996 cropping season varied between 531 mm in the north and 920 mm in the southern parts of the zone. The increase in precipitation was almost linearly with the change in latitude as one moves southwards (Kowal & Kassam, 1978). The length of the growing period is shorter in the North mainly caused by an earlier end of rain. Compared with the average values in Table 1, this indicates a large interannual variability. Rainfall variability at lower levels was not obtained.

Soils

The main soil types found in this part of the Sudan Savanna zone are classified as Entisols, Inceptisols and Alfisols. They are young immature well-drained soils formed of parent materials rich in quartz and crystalline rocks of basement complex and sedimentary deposits (Enewezor *et al.*, 1990). A common feature of these soils is their low organic content, cation exchange capacity, and nutrient content, especially nitrogen and phosphorus. At the village level, the presence of hydromophic soils occurring in inland valleys, in addition to the upland soils increases the possibilities for diversified production systems. The ethno-soil classification, however, uses only soil texture to distinguish three classes (Table 1). This may bring us a little closer to targeting technologies with respect to water use, as demonstrated in the Sudan Savanna zone of Mali (Kanté & Defoer, 1994).

Land use

At the level of the state, land use comprises both cereal-based cropping and ruminant-based livestock activities with considerable variability in most characteristics among LGAs and villages at lower scale levels (Tables 2 and 3). Averaged over the states, farm sizes increase as one moves from the south to the north, i.e. 3.9, 4.6 and 6.5 ha in the southern, middle and northern zone, respectively. These farm sizes exceed the average size of 1.2 ha in Borno state in the same agro-ecological zone (Bdliya, 1991). They are however smaller than the farm sizes in the past as indicated by Mortimore (1993a), who reported that the expansion of cultivated areas has reached its peak several decades ago.

Table 2. Selected characteristics of the nine villages in Sudan Savanna zone of Nigeria.
Tableau 2. Quelques caractéristiques des neuf villages dans la zone soudanienne du Nigéria.

State	Kano			Jigawa			Katsina			
Village	Kofa	Panda	Badume	Kantoga	Dalari	Gijigami	Gora	Rimaye	Barhim	
Subzone	South	South	Middle	South	North	North	South	Middle	North	**Mean**
Village population	1020	2260	1446	1700	1000	680	2000	900	900	1323
Households selected	10	16	11	19	19	16	19	19	15	16
Household size (-)	12	13	11	13	15	13	16	16	12	13
Working members/fam.	4	4	4	4	5	4	7	6	4	5
Farm size (ha)	4.0	4.6	3.7	3.3	8.5	4.7	3.8	5.5	6.2	4.7
No. of fields	4	3	3	4	4	4	4	4	3	3.7
Household member (ha^{-1})	3.0	2.8	3.0	2.1	1.7	2.7	4.2	2.2	4.0	2.9
Working members (ha^{-1})	1.0	0.9	1.1	1.2	0.6	0.9	1.8	1.1	0.6	1.0
Fallow	None	None	None	None	Some	Some	None	Some	None	
NPK ($kg\ ha^{-1}$)	68.1	77.3	95.0	62.4	63.0	59.8	70.6	114.0	58.5	74.3
Manure ($kg\ ha^{-1}$)	648	728	644	326	528	695	730	396	124	535.4
Cattle	3	4	4	4	5	4	3	3	2	3.6
Goat	5	7	4	5	6	4	4	4	3	4.7
Sheep	4	5	6	5	4	3	6	5	5	4.8
Chicken	13	16	15	14	12	14	10	12	10	12.9

In Kano state, land use intensity is high in Kofa and Badume, where virtually no grazing land is available for livestock during the rainy season. Badume is only about 36 km north-east of Kano city, in what is called the Kano closed- settled zone (Mortimore, 1993b). Panda is further away (73 km) from any major city with more land available for farming, resulting in the highest average farm size in this state (Table 2). In Jigawa state, the average farm size (5.5 ha) is the largest of the three states, and to some extent fallowing still exists, lasting 2-3 years (Table 2). In addition, there are communal grazing areas and woodlot plantations in the selected villages. In Katsina State, continuous cropping is very common in Gora and Barhim. Farming in Gora is highly intensified because of the former Funtua enclaved Agricultural Development Project, one of the first agricultural programs started in Nigeria. Barhim is located about 6 km south- west of Katsina city, and thus being under direct influence of markets and business of the state capital. Here, farm expansion is difficult. In Rimaye, a rural farming community not close to any major town, some fallowing can still be practiced.

Cropping systems

Cropping systems in the three states are mainly based on sorghum. On the North- South axis, the importance of sorghum increases and that of millet decreases, while groundnut and cowpea are the major cash crops regardless of the geographical position. Sole crops are predominant in the middle and northern zones, but variability in surface cultivated at both state and village level is considerable (Table 3). For sorghum, for instance, 33% of the area is cultivated with one other crop, 11% with two crops, and 7% as a sole crop. For millet, these values are 17, 3, and 4%, respectively. This implies a shift towards sorghum as compared to the 70's when the systems were dominated by millet (Gosden quoted by Elemo, 1989). Maize and rice cover together 5% and their cultivation has declined drastically in the southern part due to the high prices of fertilizers. The last group comprises other subsidiary crops, like sesame, vegetables and peppers, grown in a variety of intercrops, and covering 14% (Table 3).

The most important two- crop- system observed include sorghum/millet, sorghum/groundnut, sorghum/cowpea, millet/groundnut and millet/cowpea. For the three- crop- system, these are sorghum/millet/cowpea, and sorghum/groundnut/cowpea (Table 3). Three-crop-systems and other patterns were most common in the villages in the southern sub-zone with higher rainfall and more fertile loamy soils. Other important enterprises specific to some locations include sorghum/cotton found in Gora and Rimaye in Katsina state.

Labour force

At the village and household level, labour force is considered one of the most limiting factors by the resource poor farmers. The actual labour force for agriculture is currently about 36% of the household size (Table 2). This is lower than before due to disappearance of the 'gandu' practice, i.e. where more than one household head join together to farm and eat. Except in Gijigami village, where the majority of inhabitants are of the Kanuri tribe, female adults of child-bearing age do not work on the field, but they process the harvested produce brought home from the field. Hired labour costs constituted 20 to 30% of total production costs while total labour costs exceeded 70% of the production cost. The cost of family labour was imputed since family labour had opportunity costs in non-farm activities in the area, especially in those villages close to a state capital.

Table 3. Cropping systems in the nine villages in the Sudan Savanna zone of Nigeria in 1996.
Tableau 3. Les systèmes de culture dans les neuf villages dans la zone soudanienne du Nigéria en 1996.

	Kano			Jigawa			Katsina		
Type	Kofa	Panda	Badume	Kantoga	Dalari	Gijigami	Gora	Rimaye	Barhim
Sole									
Sorghum	8	8	9	7	6	2	8	10	7
Millet	0	3	3	0	5	10	0	10	3
Gnt	0	0	0	0	4	0	0	0	0
Maize	2	1	12	-	-	-	5	-	-
Cowpea	1	-	-	-	5	9	6	-	3
Rice	9	3	-	2	-	-	9	-	-
sub-total	20	15	24	9	20	21	28	20	13
2-Crops Mixture									
Sor/mil	14	5	9	7	6	7	11	-	7
Sor/gnt	9	14	17	9	5	-	12	15	10
Sor/cow	12	12	16	11	9	13	14	15	9
Sor/cot	-	-	-	-	-	-	9	11	-
Sor/ses	-	-	-	2	2	7	-	-	-
Mil/gnt	10	4	4	8	7	-	7	11	16
Mil/cow	8	3	5	8	9	9	6	11	11
Mil/cot	-	-	2	5	-	-	-	9	-
Gnt/cow	-	3	13	3	3	9	-	-	-
sub-total	53	41	66	53	41	45	56	72	53
3-Crops Mixture									
Sor/mil/gnt	11	9	10	8	-	6	-	-	7
Sor/mil/cow	7	8	-	12	9	13	-	-	7
Mil/gnt/cow	-	10	-	8	3	-	-	-	-
sub-total	18	27	10	28	12	19	0	0	14
Others	9	17	0	10	27	15	16	8	20
Total	100	100	100	100	100	100	100	100	100

Sor = sorghum; mil = millet; cow = cowpea; gnt = groundnut; cot = cotton; ses = sesame.

Animal husbandry

At the LGA level, animal traction is most widely practiced in the northern villages of Dalari, Gijigami and Barhim, followed by Badume and Rimaye in the middle zone. It is the least practiced in Kofa and Kantoga in the South. This pattern coincides with the reversed pattern in actual labour force, i.e. on average 0.7 working member ha^{-1} for the North compared to 1.1 for the middle and 1.2 for the South.

At the household level, sales of livestock products are very important as they bring in additional cash required for farming activities and domestic obligations. Every household keeps a varying herd of cattle, sheep and goats, and chicken, for the supply of animal power, manure and cash (Table 2). Cattle includes at least two bulls, required for animal traction, while donkeys are kept mainly for transportation. Due to the low pasture availability in most of the agro-ecological zone, there is usually a great demand for animal feed, especially during the dry season. Crop residues are the principal source for this, so that in addition to grains also stover may bring in cash.

Fertilization

Due to the absence of fallow, both chemical fertilizer and organic manure are used to maintain and improve soil fertility. The high cost and scarcity of fertilizers owing to poor distribution systems in recent years have forced farmers to use more animal manure, which is now applied at an average rate of about 535 kg ha^{-1}. Farmers prepare their manure in the compounds on the basis of droppings from ruminants and poultry, and crop residues. Because the quantity of manure produced by farmers is usually insufficient to cover the whole farm in any given year, it is only applied to specific spots in the field with each field receiving manure every two to three years.

The most popular chemical fertilizer is the compound NPK (20:10:10), but the amount of fertilizers applied is limited. An average household obtains a total of 150 to 250 kg of this NPK, which is applied at an average rate of 74 kg ha^{-1} (Table 2). Applying average N, P, and K contents of manure of 1.27, 0.28 and 1.30 g kg^{-1} on DM basis, respectively (Van Duivenbooden, 1992), together with the chemical fertilizer, the total external nutrient inputs amount to 21.6, 8.9, and 14.4 kg ha^{-1} for N, P and K, respectively. Assuming average nutrient uptakes requirements and fertilizer efficiencies (Van Duivenbooden *et al.*, 1996), these inputs should be sufficient on poor soils for a millet yield of about 250-300 kg ha^{-1} and for sorghum of 250-350 kg ha^{-1}. Since currently yields of about 500-700 kg ha^{-1} are obtained, this implies that in most cases soil nutrient mining occurs in all villages.

Financial returns

Financial returns per hectare for crop mixtures were higher than those for sole crops (Table 4). This partially explains why farmers grow crops in mixtures. The average gross margins over the three states was 9347 Naira ha^{-1} for sole crops. For the 2-crops and 3 -crops mixtures, returns were larger: 37 and 59%, respectively. This indicates clearly the importance of mixed production systems in this zone.

Table 4. Production costs and returns (Naira ha^{-1}) for different types of cropping systems in Kano, Jigawa and Katsina states, Nigeria.

Tableau 4. Les couts de production et les revenues (Naira ha^{-1}) pour les differents types des systèmes de culture dans les états de Kano, Jigawa et Katsina, Nigéria.

Types of systems	Kano			Jigawa			Katsina			Average net revenue (3 states)
	Total cost	Total revenue	Net revenue	Total cost	Total revenue	Net revenue	Total cost	Total revenue	Net revenue	
Sole crop	6216	18100	11884	5539	14000	8461	6050	13750	7700	9347
2-crops mixture	7287	22717	15430	6572	17867	11295	6721	18420	11699	12808
3-crops mixture	7089	26933	19844	6918	17300	10382	6388	20700	14312	14846

US$ 1 = 79 NAIRA

Constraints

On the basis of these results and additional (non-published) information, Table 5 has been derived. It clearly shows that constraints occur at each level of the distinguished scales. Although not made explicit in the table, differences occur between states. This implies that technologies and interventions should address different scales and spatial variability. As a consequence, for monitoring impact of interventions these scales should all be considered.

Selection of benchmark sites

On the basis of these results, the following characteristics were considered as determinant for the selection of the benchmark sites: rainfall, distance to town, farm size, cropping system, and logistic reasons. Although nine villages were surveyed in the three states, the three benchmark sites being recommended are all located in Kano state, mainly for logistics reasons, while still all characteristics of the Sudan Savanna zone can be found in these three sites. The selected sites are Kofa, Gargai and Badume. It is, however, recognized that all variability cannot be captured (e.g. soil type) in this selection. The constraints identified at each level need to be taken into account when making recommendations to policy makers and farmers on the basis of research results from these benchmark sites.

The Kofa benchmark site represents the wettest part of the Sudan zone with an annual rainfall of 889 mm and is within the Bebeji LGA. It is about 80 km from Kano city and 6 km off the Kano-Zaria road. Although it is densely populated it has no village market. It has little room for farm expansion of the sorghum-based system. Cultivation is mainly manually done, with animal traction being virtually absent.

The Gargai benchmark site, in the same LGA, has an average annual rainfall of 800 mm. It is about 66 km from Kano city, and although closer to cities than Kofa, it is less densely populated, leaving some room for farm expansion. It is accessible with good road and is very close to a relatively bigger town, Tiga and its market. Its proximity to the Tiga dam allows farmers to practice dry season farming using irrigation water. The cropping system is mainly sorghum based with some use of animal traction.

The Badume site, in the Bichi LGA, lies between the dry northern and wet southern parts of Kano state. It has an annual rainfall of about 700 mm. The main road linking Kano state (through Katsina state) to Niger republic passes through this village. The site is about 40 km north of Kano city, and represents mainly the millet-based production systems, and secondly the sorghum-based ones. Groundnut production is also very important and trading is a major non-farm occupation.

Table 5. Generalized constraints in Kano, Jigawa and Katsina states, Nigeria.

Tableau 5. Contraintes généralisées dans les états de Kano, Jigawa et Katsina, Nigéria.

Identifier	State	LGA	Village	Household	Production system
Infrastructure	Investment in paved roads only	Quantity and quality of laterite roads	Accessibility	Means of transport (donkeys and ox-charts)	Labour which could be used for other purposes
Population	Rapid population growth and urbanization	Land scarcity around cities	Land tenure: fragmentation of land due to inheritance; lack of grazing and fallow land	Land far from homestead; time requirements for walking; number of animals that can be kept; no space for extension	Fallow and manure availability required for soil fertility restoration; soil mining; overgrazing
Physical environment	Low soil fertility	Low soil fertility	Low soil fertility; Lack of subsidized fertilizer	Lack of financial means to buy fertilizer	Low soil nutrient availability
	Low and erratic rainfall	Low and erratic rainfall	Lack of water supply (dry season)	Drinking water for humans and animals	Droughts
Inputs	Poor distribution system of subsidized fertilizer and other inputs	Service centres do not have the required inputs;	Lack of inputs and credits	Lack of financial means to buy improved seeds, etc.	Low yield potentials
Credit/extension/services	Poor credit, extension and insurance services	Ineffective extension service Degraded tractor-hiring services	Absence of cooperations/ farmer's organization Lack of traction power	Limited access to extension knowledge Labour availability in June-July; inadequate farm tools	Lack of improved technologies Weeds; higher labour requirements
Marketing	Poor distribution system	Absence of agro-industry	Lack of processing and preservation facilities; Absence of village markets	Possibilities to raise money	Reduced cash crop cultivation
Biological constraints	-	-	-	-	Parasitic weeds, insects and diseases (e.g. downy mildew)

Conclusions

Three benchmark sites, Kofa, Gargai and Badume were selected in Kano state in northern Nigeria using a multi-scale characterization method and on the basis of five criteria, i.e. rainfall, distance to town, farm size, cropping system and accessibility. It is recognized that all variability cannot be captured (e.g. soil type), but with this multi-scale approach constraints and opportunities at each scale level were better identified. This will help in better formulation of recommendations for (agricultural) development and targeting of technologies and interventions to specific environments, based on results related to predominantly mixed production systems from those benchmark sites.

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