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Variations on a theme: conceptualizing system diversity with examples from northern Cameroon

B de Steenhuijsen Piters, L Fresco

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Variations in system output

One of the major assumptions of farming system research (FSR) concepts is that within a given environment, systems (or subsystems) can be characterized by a certain degree of homogeneity. This is underscored by the concept of recommendation domains (Byerlee and Harrington, 1982; Fresco, 1986). The recommendation domain assumes inherent uniformity within farming and cropping systems and a direct relationship to system output. Given the same agroecological and socioeconomic conditions, significant variation in system output is not to be expected.

However, there is evidence – albeit poorly documented – that heterogeneity is more likely than homogeneity, even if the external conditions appear, on the surface, to be the same. For example, in a sample of farmers' fields in a village in northern Cameroon, sorghum (*Sorghum caudatum*) yields over three consequent years varied considerably (Table 1).

Within what appears to be the same cropping system in a well-defined geographic and socioeconomic range, there is a high degree of yield variation that is quite stable over the three years of study. High variability did not occur at field level only. At household level, total sorghum production was found to vary considerably, when all measured sorghum yields were cumulated for each of the 46 randomly chosen households in one village (Figure 1). Household sorghum production ranged from 2,000 kg to 18,000 kg, resulting in occasional food shortages in some households and high sales and income in others.

Such high variation in output at both levels (farming and cropping systems) leads to the questions: What induces these variations? How should they be addressed? They are particularly relevant because entire villages and sometimes even districts are lumped together when defining recommendation domains for planning and extension purposes. Although there is an obvious need to group farms and farmers at various levels of aggregation, this must be done with due recognition of the variability at each level.

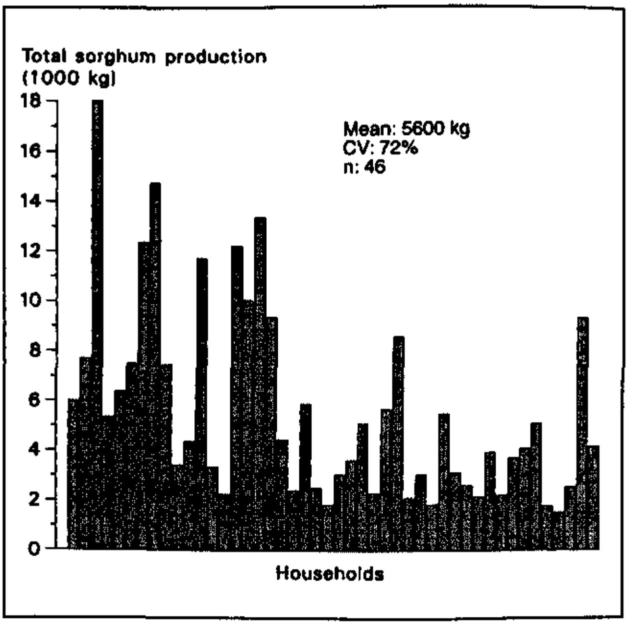
We propose to examine the existence and significance of variation at cropping and farming systems levels through a case study in northern Cameroon.

Table 1 Yield variation in rainfed sorghum in the village of Gaban, northern Cameroon

Year	Number of fields	Yield (kg/ha)[a] Mean	Minimum	Maximum	CV (%)
1991	44	1900	500	4300	52
1992	137	2500	200	5500	51
1993	40	1600	300	3200	47

[a] At 12% grain moisture

Figure 1 Histogram of total sorghum production per household in 1992 in the village of Gaban, northern Cameroon



System diversity as a problem

In agricultural research, yield variations have been observed ever since the beginning. They must have been among the factors that prompted research in the first place. Researchers have worked on variability problems since the early 1900s (Vieira et al., 1982). As early as 1913, high variation was reported for wheat yields even when conditions appeared quite uniform (Montgomery, 1913). Yield variation was generally seen as a problem, and the solution was to eliminate it through the adaptation of sampling schemes, e.g. increasing the number of replications and selective placement of plots, and the development of sampling methods and statistical methods of analysis, such as analyses of variance and covariance.

Soil variability traditionally had a negative connotation, as it was considered a factor that complicated interpretation of results of agricultural experiments (Moormann and Kang, 1978), biased results from experiments and reduced researchers' ability to detect treatment differences (van Es and van Es, 1993). The effect of (spatial) variability on crop growth and production is commonly understated. Although it has been known for at least 90 years, it still is regarded as a major disturbance that has to be eliminated from experiments and trials. This necessity was particularly stressed by Chase et al. (1989), who stated that 'the objective of the studies reported was to determine the causes of variability and to seek methods to eliminate the sources of this variability'.

Diversity as a source of information

During the past decades, temperate agriculture and forestry has often been aimed at specialization to maximize output from such systems (Huxley, 1986). An essential element of this production maximization effort was the control and manipulation of environmental heterogeneity. It resulted in a homogenization of the landscape. Recently, however, there is a growing awareness that variability is a widespread phenomenon and that, under certain conditions, it may also be an advantage. This was already recognized by one of the founding fathers of FSR, Pierre de Schlippe, in his study of field-level heterogeneity in shifting cultivation (de Schlippe, 1956). In subsistence farming systems in the semiarid tropics of western Africa, where nutrient and water availability alternately limit agricultural production, soil and crop growth microvariability may be an asset to farmers (Brouwer et al., 1993). Huxley (1986) arrived at the same conclusion for agroforestry systems and showed how environmental heterogeneity can be turned into an advantage.

Farmers in low-input agriculture, in particular, try to exploit heterogeneity both in space and time. For example, a small farmer will often arrange crops and varieties according to the varied pattern of soil fertility across the field. Under these conditions, environmental heterogeneity is not controlled or excluded, but managed through adaptation of agricultural practices to the biophysical environment.

Environmental heterogeneity may also be a product of human interference. There are numerous examples of agricultural systems in sub-Saharan Africa where soil fertility differences have developed as a function of system management, with distance to the fields as an important variable (Benneh, 1971; Lagemann, 1977; Prudencio, 1993). Transport and concentration of soil fertility leads to variation in land use intensity. Differences among farmers – in access to the means of production and in production goals – will create differences in the conditions in which agricultural production takes place. This social or cultural diversity includes intrahousehold dynamics, involving the division of resources and specific production goals between male and female farmers. The point that is often missed is that socioeconomic differences result in the diverse use of land.

Table 2 Variation in rainfed sorghum yields and explanatory variables according to field type in the village of Gaban, northern Cameroon, 1992

Variable[a]	All fields	All Toupouri fields	Moundang fields			
			All	≤0.1 km[b]	0.1–0.5 km[b]	≥1.0 km[b]
Number	137	48	90	25	20	45
Mean yield (kg/ha)	2500	3110	2130	3400	1760	1580
CV (%)	51	36	56	32	65	38
R^2 (%)	63	69	71	54	64	70
Distance	–.170					
Quantity of manure	.140		.184			
Plowing		.154		.272	.284	.527
Sowing date	–.216	–.311	–.259		–.309	–.434
Number of weedings	.184					
First weeding date			–.178			–.552
Total weeding time	.191	.215	.187	.589		
Cv Gling	.237					
Plant density	.386	.605	.449		.635	.508
Striga infection	–.211	–.173	–.220	–.651		–.336
Quantity of urea	–.195					
Sandy-clay soil			.144			
Area						.311

[a] Figures following variable names refer to the standardized regression coefficient of each variable (pad coefficient)
[b] Distance class depending on distance from homestead

System diversity at field level

In a study in the village of Gaban, northern Cameroon, all variables with a possible effect on yield were measured and recorded during the growing season for 137 fields of rainfed sorghum (de Steenhuijsen Piters and Fresco, 1994). The variables comprised biophysical characteristics of the fields, inputs and farmers' practices. A multiple regression analysis of the variables was carried out to explain rainfed sorghum yield.

Without any stratification of the fields, 9 of the initial 55 variables were able to explain 63% of total sorghum yield variation in 1992 (Table 2). This result was not satisfactory because of the large number of variables, poorly explained variance and flat pad coefficients (standardized regression coefficients).

To improve the results, the fields were stratified according to the ethnic origin of the farmers. In the case of one ethnic group, the Toupouri, stratification reduced yield variation, increased explained variance, decreased the number of variables and enhanced the contrast among the pad coefficients. An additional stratification was needed for the Moundang fields. Spatial field patterns based on observations, discussions with the

Table 3 **Family size and distribution of means of production according to household class in the village of Gaban, northern Cameroon**

Parameter	Low-resource households (n = 13)	High-resource households (n = 18)	2-tailed significance level
Family size			
– Consumers	5.5	9.7	<0.01
– Workers	3.4	5.8	<0.01
– Consumers/workers	1.8	1.7	–
Means of production			
– Ox-drawn plows	0.0	1.3	<0.001
– Donkey-drawn plows	0.2	0.6	–
– Ox-drawn carts	0.0	0.4	<0.005
– Oxen	0.1	2.7	<0.001
– Cows	0.0	6.4	<0.001
– Donkeys	0.3	0.5	–
– Sheep and goats	2.8	12.9	<0.001
– Estimated available amount of manure (kg)[a]	300	3700	<0.001
Rainfed acreage (including fallow) (ha)			
– Total	2.3	5.0	<0.005
– Area/worker	0.8	0.9	–

[a] The estimates of available manure/animal are based on those applied for the fifth region in Mali by van Duivenbooden et al. (1991)

farmers and previous work (Lagemann, 1977; Benneh, 1971) were taken into account to improve the results of the multiple regression analysis.

Three different field types were distinguished according to the distance from the homestead. Each field type had a specific yield level; yield variation was explained by specific combinations of variables, which differed among the three field types. The field types were therefore defined on the basis of spatial distribution of specific multi-dimensional interactions among biophysical, technical and input-related variables. For example, in the first field type (0.1 km from the homestead), there is an interaction between the 'sandy-clay' soil texture class and high organic manure application, early ploughing and sowing dates, and high plant density, which results in high but variable yields. Another example is the interaction in the third field type (1–7 km from homestead) between the 'clayey-sand' soil texture class and relatively high fertilizer application, variable ploughing and sowing dates, low plant density, and frequent intercropping with cowpea (*Vigna unguiculata*), which results in low, almost uniform yields.

The degree of observed yield variation cannot be regarded as residual or an error term of the model. It is not a product of random human intervention but the result of deliberate human action in a heterogeneous environment. Stratification into units that reflect this functional interaction may lead to a higher and more satisfactory explanation of system diversity at field level.

Table 4 **Land distribution (excluding fallow) according to Moundang field type in the village of Gaban, northern Cameroon, 1992.**

Field type	Mean acreage (ha)		2-tailed significance
	Low-resource households (n = 13)	High-resource households (n = 18)	
Type 1 (≤ 0.1 km)	0.14	0.43	<0.001
Type 2 (0.1–0.5 km)	0.19	0.63	<0.001
Type 3 (1.0–7.0 km)	0.77	1.83	<0.001

System diversity at household level

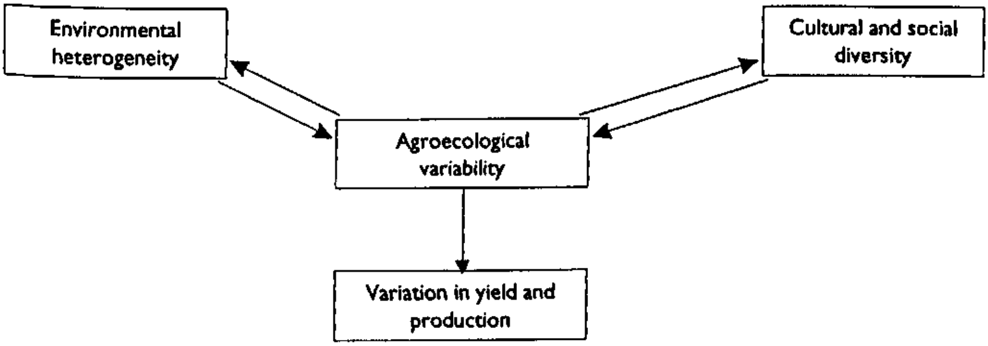
Moundang households can be categorized on the basis of ownership of ploughs, oxen and cattle, which corresponds to results showing the importance of ploughing and organic manure application at field level. The terms 'low-resource households' and 'high-resource households' are employed to stress that the categorization includes more than equipment for mechanization. According to a checklist of all households with key informants, 44% indicates a high-resource household and 56% a low-resource household.

High-resource households are formed by larger families, which therefore have a larger number of family workers than low-resource households (Table 3). But the ratio between consumers and workers is not significantly different between the two household classes. Each worker has to support fewer than two consumers. High-resource households possess at least one plough and one pair of oxen. Moreover, these households own all the large cattle and most of the small ruminants. Consequently, they also have a larger share of the total available amount of manure, which is almost 12 times the amount that is available to low-resource households.

High-resource households cultivate almost twice the acreage compared with low-resource households, but total rainfed acreage and area/worker ratios are not significantly different between the two household classes. However, land distribution across the three field types defined in Table 2 is not uniform for the two household classes (Table 4). Corrected for their proportional importance in the village, high-resource households own and cultivate 70% of the land in the first field type, which produces the highest yields (Table 2). High-resource households therefore possess the necessary means of production (animal traction, manure); they also have absolute dominance over fields near the homestead. Both these factors explain why these households obtain high sorghum yields. Low-resource households do not possess these essential means and their fields are relegated to the periphery of the village territory. Soil mining is a common practice in these lands, but this system is labour-intensive, risky (birds, elephants) and unstable (decreasing soil fertility). All these factors contribute to low yields and, occasionally, result in food shortages.

The means of production, which basically determine the farming system, are not uniformly distributed across the households. This skewed distribution results in varied

Figure 2 Diversity in farming systems (the different elements are not scale-independent)



land use and variable production results. Analysis of this internal diversity is essential for the understanding of variations in system output. The factors that determine agricultural production through their actual distribution, interactions and impact within the social and biophysical environment should be analyzed. Only then can production strategies and household situations concerning food and income be clearly understood.

Conceptualizing diversity in farming systems

Since the 1980s, elements of system diversity have been integrated in systems approaches developed by French researchers (Tallec, 1986; Bédu et al., 1987; Garin, 1989; Yung and Zaslavsky, 1991). Moreover, social scientists have studied social differentiation and diversity as essential, structural phenomena in the process of agrarian production (Mendras, 1970; van der Ploeg, 1990). Diversity and variation are increasingly seen as important sources of information for analysing agricultural processes in realistic conditions. But decades of development of techniques and methods to eliminate sources of diversity and variation have still not led to a well-defined, integrated approach for analysing and explaining the causes of yield and production variation in agroecological systems.

The terms 'variation', 'variability', 'diversity' and 'heterogeneity' appear regularly in literature with apparently interchangeable meaning. A clear definition of relevant terminology is indispensable. The following definitions are proposed based on McBratney (1992), and Shachak and Brand (1993):

- variation: fluctuations in the values of one variable
- variability: tendency or ability to vary
- heterogeneity: state of being composed of parts of different kinds
- diversity: state of being composed of parts of one kind (being multiform).

Table 5 Conceptual framework for analysis of diversity in farming systems

Source	Level of analysis	Units of analysis	Mechanism	Result
Environmental heterogeneity, cultural and social diversity	Farming system	Ethnic group, household, producer	Specific allocation of available means of production for agricultural and nonagricultural activities	Variation in production of food and surplus
Agroecological variability	Cropping system	Crop, field	Specific combination of biophysical field characteristics, inputs and cropping techniques in space and time	Variation in yield and input/output ratios

The term 'heterogeneity' is frequently applied to indicate differences in abiotic factors of an environment, such as landscape units or soil types. Diversity usually refers to a population, as in the case of species diversity, ethnic diversity or household diversity. The interaction between environmental heterogeneity and population diversity may be defined by the term agroecological variability, which is the ability or tendency of land use to vary in space and time (Figure 2).

A framework was developed to facilitate distinction of relevant elements for analysing system diversity and placing them in a dynamic perspective (Table 5). It stresses the need to quantify the relations among variables of different origin and to link levels of analysis. The range and distribution of variables are of crucial importance.

Conclusion

System diversity is an important phenomenon which has been ignored for too long. There are no clear concepts or methods to fully understand it. However, there is a growing awareness that it is an important feature of agroecological systems, especially those in marginal and less controllable conditions. In situations of uncertainty, diversity may even be considered an asset to farmers. Diversity in systems should be regarded as an important source of information on how farmers respond to their environment. A clear understanding of system diversity will improve research efforts to develop effective solutions to agricultural problems and to support local people in their development efforts.

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