Validation of land evaluation methods for performance assessment of traditional agroforestry systems in South West Cameroon[1)]

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Abstract

Smallholder farms in humid tropics often display complex associations of perennial and annual crops as farmers tend to valorise between-row spaces of the perennials by intercropping with shorter cycle crops, all in a bid to better absorb climatic and associated economic risks. To better understand the functioning and performance of such systems, the flow of farm inputs and production should be properly monitored. This study was conducted to assess the suitability of traditional land evaluation and multivariate statistical analysis to define relatively homogeneous entities or farm section units (FSU). Data obtained from several perennial crop-based farms were analysed using a traditional land evaluation technique and multivariate statistical analysis. Irrespective of the evaluation method, all parameters varied considerably for the plots surveyed. The zones differed with respect to their altitudes, farm holding size, annual rainfall, and slope of fields. Although both evaluation systems seemed complementary, results obtained did not always converge owing to differences in the nature and magnitude of criteria considered. These results demonstrate the feasibility of complementing traditional land evaluation with some multi-variate statistical analysis to classify perennial crop based farming systems.

Keywords: multivariate statistical analysis, traditional land evaluation, farm section unit, perennial crop, multi-storey farm holding, Tropical humid forest, Cameroon

Zusammenfassung

Validierung von Methoden zur Bewertung traditioneller Agroforst-Systeme in Südwest Kamerun

Kleinbäuerliche Landwirtschaft in den Tropen bestehen zumeist aus einem komplexen Gemisch ein- und mehrjähriger Kulturen mit dem Ziel, den Raum zwischen den mehrjährigen Kulturen bei gegebenen klimatischen und pedologischen Bedingungen möglichst optimal zu nutzen, und das ökonomische Anbaurisiko zu minimieren. Ziel der Untersuchungen dieser Arbeit war es, die Eignung traditioneller Landbewertungssysteme für derartig komplexe Situationen zu überprüfen und mit den Klassifizierungsergebnissen multivariater statistischer Methoden zu vergleichen. Bedingt durch die Vielzahl der in die Bewertung bzw. multivariate Analyse aufgenommenen Parameter wurde im Ergebnis eine relativ hohe Übereinstimmung beider Ansätze erreicht.

Multivariate statistische Verfahren erscheinen demnach geeignet, die erheblich arbeitsaufwändigeren klassischen Methoden der Landbewertung wenn nicht ganz zu ersetzen, doch wirksam zu unterstützen.

Schlüsselwörter: Agro-Forstwirtschaft, humider Tropenwald, Kamerun, kleinbäuerliche Landwirtschaft, Landbewertung, multivariate statistische Analyse

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1 Introduction

Land evaluation is concerned with the assessment of land performance when used for specified purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use (Soil Resources Development and Conservation Service, 1976). Peasant agriculture, in humid tropical countries, is characterised by particular links it establishes between the multiple objectives of farm holdings, considerable mobilisation of family labour, farmers' resolved attachment to land, and variable use of external farm inputs. The farms are often characterised by different production systems, which are more or less coherent combinations of the various means of production. In the humid tropical zones of South West Cameroon, the cropping systems frequently present complex and varied combinations of perennial plantation crops like the rubber tree (*Hevea brasiliensis*), cocoa plant (*Theobroma cacao*) or the oil palm (*Elaies guineensis*), in association with other annual crops. The vegetative development of the perennials covers an immature growth phase and a mature productive phase. The former phase could last for variably long periods (2 to 8 years) depending on the species, the quality of the planting material used and field upkeep. To ensure a livelihood during the trees' immature phase, these farmers indulge in multi-storey multi-cropping systems during which they tend to valorise between-row spacings for food crop associations.

Much effort has been geared in the past towards improving the quality of smallholder agriculture but few seem to appreciably modify the production methods of these farm holdings. Although the multi-storey cropping systems have the capacity to absorb the main climatic and economic risks associated with crop cultivation, not much is known about their functioning, performance and durability. Even methods and criteria adopted to evaluate intensive monoculture systems have seemed insufficient and inappropriate for them. As part of an overall study to evaluate nutrient status/flows and economic performance of tropical cropping systems using a diagnostic software called "Nutmon ®" (2006), there is need to undertake soil sampling and geo-referencing of plots and design the different farm section units (FSUs). The Nutmon ® software has been deemed particularly useful to ensure a proper follow-up and monitoring of all inputs and production from farm holdings which had previously been characterised in terms of some climatic and morpho-pedological data (De Jager *et al.*, 1998). In fact, the Nutrient Monitoring (NutMon) methodology was developed as a decision support tool for the integrated analysis of farming systems; to facilitate planning and improve farm management.

The purpose of this study was therefore to validate, using multivariate statistics, traditional land evaluation techniques used for the definition of each FSU and then constitute FSUs for some perennial crop based farm holdings in the humid forests of South West Cameroon. In theory, the NutMon ® software is applicable for independent plots in a holding or firm. Hence, the different zones of intervention were considered as farm firms (Farm Section Unit or FSU) constituted of relatively homogeneous morpho-pedological entities or plots defined as primary production units (PPU) wherein the various crops were cultivated. Each FSU was defined as a function of the relief (slope, especially), soil characteristics, climatic data, etc..

2 Methods

2.1 The study area

The study was undertaken in the first quarter of 2007 (January to March) and covered thirty eight (38) perennial crop-based farms situated in four villages in the humid forest belt of South West Cameroon (Figure 1): The villages of Bombe, Banga Bakundu, Etam II and Mukonje, respectively in Muyuka, Mbonge, Tombel and Kumba subdivisions. These survey loci could be spatially divided into two zones, notably the Kumba South region (Bombe and Banga Bakundu) and the Kumba North region (Etam II and Mukonje).

The humid forest zone is characterised by warm temperatures (~ 23°C) evenly distributed throughout the year, high relative humidity (76 to 90 %), deep fertile soils with pockets of ferruginous and very fertile volcanic soils, and rather high annual rainfall (> 2500 mm) spread out in two distinct seasons – a rainy season from April to October and a dry season from November to March (Ehabe et al., 1990).

The zone was also characterised by several farm types: small-scale farm holdings with mostly food crops (banana, plantain, cocoyam, cassava, yam, maize, etc.), industrial plantations for the production of export crops like oil palm, hevea, cocoa, coffee, tea, etc., and intercropped farms having various combinations of perennial and food crops (Plaza, 2003).

2.2 Constitution of samples

The chosen villages were characterised by homogeneous farm holdings, intense agricultural and non-farm economic activities (Ebongue, 2006; Nguinlong, 2007) as well as the presence of small to medium-sized plantations with the rubber tree (*Hevea brasiliensis*), oil palm (*Elaies guineensis*) or cocoa (*Theobroma cacao*) as main crop in association with other food or cash crops. Thirty eight (38) farm holdings were visited that had been judged sufficiently repre-

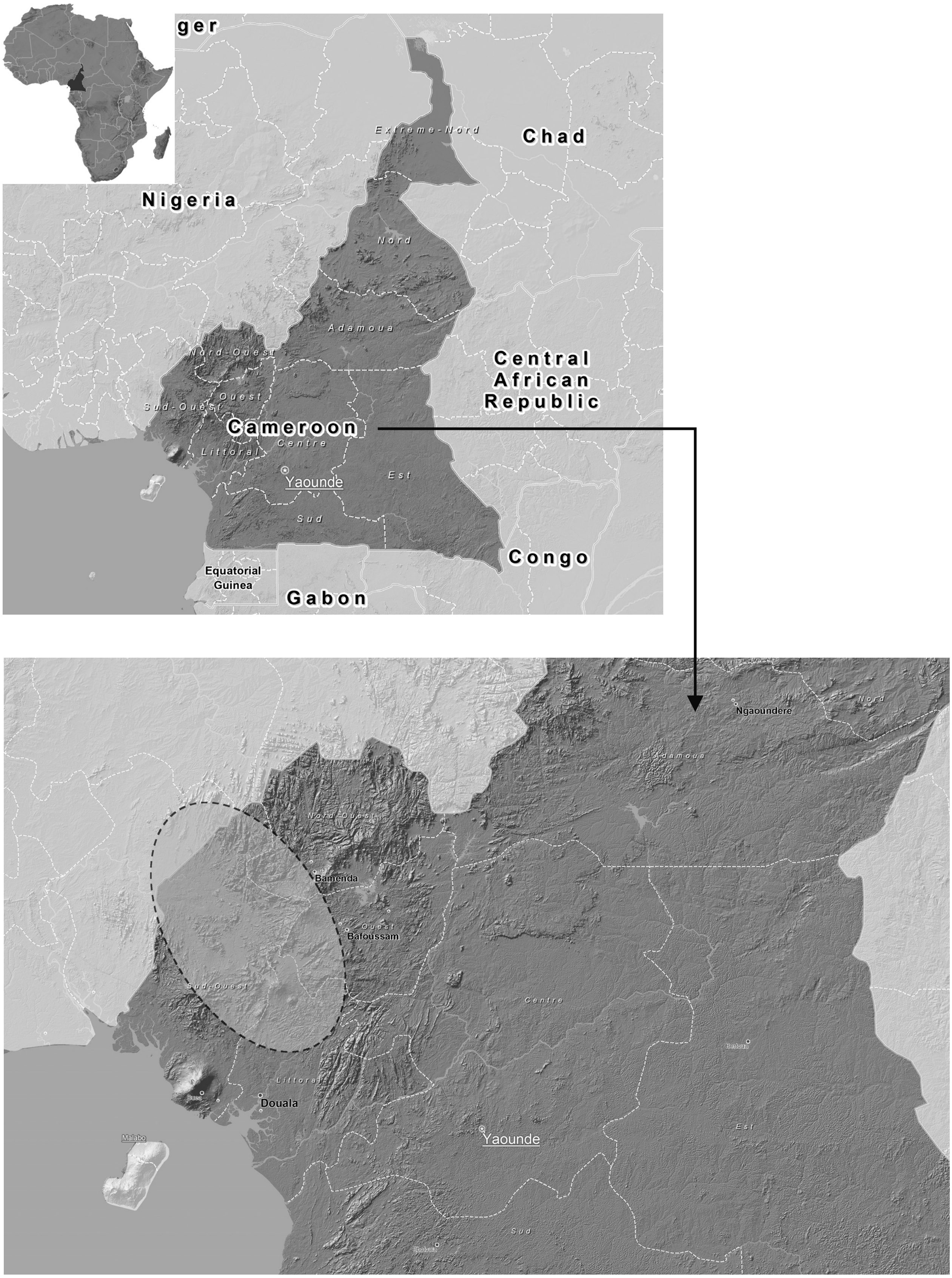

Figure 1:
Map of the zone of study

sentative with respect to the different exploitation systems, the presence of different stages of development of the principal perennial crop, and accessibility of the fields.

2.3 Data collection and codification

Each field was characterised for its location, altitude and surface area (using a Global Positioning System, GPS), relief and soil morphology (depth, texture or clay content) and the owner of the property. Climatic data like mean annual rainfall (C) for each field were obtained from the nearest meteorological station and the values regrouped as follows: A value of "C1" was given for excellent (> 3000 mm), "C2" for average (2000 to 3000 mm) and "C3" for slightly poor (~ 2000 mm) for crop cultivation. The following parameters were recorded for the upper soil profile (0 to 30 cm) of each farm: slopes (S), moisture status (M) and rooting status (R). Some field data that could not be recorded as continuous variables hence had to be transformed for principal component analysis (Ehabe *et al*., 2001):

- Soil clay content (c): Shallow = I (15 to 20 cm); Average = II (20 to 35 cm); Deep = III (> 35 cm);
- Soil colour: Brown to dark brown = 1; Grey to dark grey = 2; Black to dark black = 3;
- Parent material: Volcanic = 1; Volcanic/Basement complex = 2.

2.4 Statistical analysis

Two approaches were adopted for the definition of a FSU – one based on the traditional land evaluation expert system and the other on multivariate statistical analysis of the data.

For the statistical method, coefficients of correlation characterizing the intensity of the linear relationships between all discrete data were performed. These relationships were further analyzed using the principal component analysis technique (Philippeau, 1986; Ma et al., 2000; Onywere et al., 2000). Correlation matrices were used to produce principal component bands (PC's). These were linear combinations along orthogonal axes featuring the direction of maximum variance (PC1) where most spread in the scatter plots were observed, while the other axis (PC2) described variance in data not already described.

3 Results and discussion

3.1 Definition using the land evaluation method

Using the traditional land evaluation technique, the entire collected data could be used to define 10 FSUs (Table 1).

- FSU_1 involved 7 plots with an annual rainfall of 2000 to 3000 mm, gentle slopes (< 5 %), sufficient soil moisture, loamy soils with low clay content or higher amounts but in about equal amounts of silt and sand;
- FSU_2 involved 9 units characterised by a higher than average annual rainfall (2000 to 3000 mm), gentle slopes (< 5 %), moist and loamy soils with low clay content;
- FSU_3 involved 2 units with average annual rainfall (2000 to 3000 mm), slopes of less than 5 %, dry soils, and soils with slight or no clay. The FSU included two fields in Bombe: cocoa with excellent rooting and a rubber farm with poor rooting;
- FSU_4 involved 6 units with an annual rainfall higher than 3000 mm, gentle slopes (< 5 %), slight to averagely moist and sometimes dry soils, and loamy soils with low clay content and sometimes contained balanced amounts of silt and sand;
- FSU_5 involved 4 units - cocoa and oil palm fields with excellent rooting, and rubber fields with average rooting, all characterised by high annual rainfall (> 3000 mm), gentle slopes (< 10 %), slightly moist or dry soils, and low clay content;
- FSU_6 involved 2 units with average annual rainfall (2000 to 3000 mm), slopes of 5 to 10 %, and low clay content. The FSU included a field in Mabonji oil palm where rooting was poor and in Bombe oil palm where rooting was equally poor;
- FSU_7 involved 3 units with high annual rainfall (≥ 3000 mm), slopes of 10 to 15 % but at times less than 5 %, and low clay content. The FSU included a field in Malende oil palm where rooting was poor and another in Ebonji cocoa where rooting was excellent;
- FSU_8 involved 2 units in Malende, one with cocoa with excellent rooting and another with cocoa with poor rooting. Annual rainfall was low (≤ 2000 mm), average slopes (5 to 10 %), averagely moist and dry soils, and low to average clay;
- FSU_9 involved 3 units with average annual rainfall of 2000 to 3000 mm, high slopes (≥ 15 %), slightly moist soils, and low to average clay;
- FSU_{10} involved just 1 oil palm unit in Malende unit with low annual rainfall (≤ 2000 mm), slopes of 10 to 15 %, dry soil, and slight clay. Rooting was average.

Table 1:

Farming Section Units (FSU) identified using the land evaluation method

Field	Village	Crop	FSU	Classification	Rooting quality
1	Small Ekombe	Cocoa	FSU1	C2S1M1c1R4	Poor
5	Small Ekombe	Cocoa	FSU1	C2S1M1c3R4	Poor
11	Mukonje	Cocoa	FSU1	C2S1M1C2R3	Slightly good
22	Bombe	Cocoa	FSU1	C2S1M1c3R1	Excellent
24	Bombe	Cocoa	FSU1	C2S1M1c3R2	Just good
31	Bombe	Oil palm	FSU1	C2S1M1c2R4	Poor - shallow topsoil
35	Bombe	Hevea	FSU1	C2S1M1c2R2	Average
13	Mabonji	Oil palm	FSU2	C2S1M3c1R4	Average
15	Mukonje	Oil palm	FSU2	C2S1M3c1R1	Slight
18	Mukonje	Oil palm	FSU2	C2S1M3c1R2	Poor
19	Mukonje	Oil palm	FSU2	C2S1M3c1R2	Excellent
29	Bombe	Oil palm	FSU2	C2S1M3c1R1	Averagely good
32	Bombe	Oil palm	FSU2	C2S1M4c1R4	Poor
33	Bombe	Hevea	FSU2	C2S1M4c1R3	Good
34	Bombe	Hevea	FSU2	C2S1M4c1R2	Less rooting
36	Dschang Quarter	Hevea	FSU2	C2S1M3c1R2	Good
20	Bombe	Cocoa	FSU3	C2S1M4c2R4	Excellent
37	Bombe	Hevea	FSU3	C2S1M4c2R1	Poor
2	Ebonji	Cocoa	FSU4	C1S1M4c3R4	Poor
4	Etam 1	Cocoa	FSU4	C1S1M4c2R1	Average
6	Etam 1	Cocoa	FSU4	C1S1M2c3R2	
9	Etam 2	Cocoa	FSU4	C1S1M3c1R1	Excellent
10	Ebonji	Cocoa	FSU4	C1S1M3C1R3	Slight
16	Ebonji	Oil palm	FSU4	C1S1M3c1R2	Poor
3	Etam 1	Cocoa	FSU5	C1S2M3c1R1	Excellent
7	Etam 1	Cocoa	FSU5	C1S2M3c1R1	
12	Etam 2	Oil palm	FSU5	C1S2M4c1R1	Excellent
19	Etam 1	Hevea	FSU5	C1S1M4c3R2	Average
14	Mabonji	Oil palm	FSU6	C2S2M4c4R4	Poor
30	Bombe	Oil palm	FSU6	C2S2M4c1R4	Poor
8	Ebonji	Cocoa	FSU7	C1S3M3c1R1	Excellent
23	Malende	Cocoa	FSU7	C3S1M3c2R4	
28	Malende	Oil palm	FSU7	C3S1M4c2R4	Poor
21	Malende	Cocoa	FSU8	C3S2M4c1R1	Excellent
25	Malende	Cocoa	FSU8	C3S2M2c3R4	Poor
17	Mukonje	Oil palm	FSU9	C2S4M3c2R1	Excellent
26	Bombe	Cocoa	FSU9	C2S4M1c3R3	Slight
38	Bombe	Hevea	FSU9	C2S4M3c3R1	Excellent
27	Malende	Oil palm	FSU10	C3S3M4c2R2	Average

Definition using the statistical analysis method

All the parameters measured varied considerably for the analyzed plots, irrespective of the zone in which they were situated (data not shown). In terms of altitude, the two zones (regions) covered were distinctly different. Villages in the Kumba South zone (Bombe Bakundu and Malende Muyuka) were typically low-lying while those in the Kumba North zone were of higher altitudes (> 100 m asl). These two zones equally varied with respect to the sizes of farmholdings, the average annual rainfall, and the slope of fields. The fields were generally larger in Kumba North zone (0.35 to 4.0 ha) than in Kumba South zone (0.07 to 2.36 ha). In a similar manner, rainfall was higher in Kumba North than in Kumba South.

No clear trends were observed with respect to the field-to-field variation of soil's depths, clay and moisture contents, as well as the surface characteristics, the gravel content, the soil colour and parent material. Coefficients obtained from the analysis of principal components showed that the first two principal components (P1 and P2) accounted for more than 99 % of the total variation in the data collected: 99.94 % for PC1 and 0.04 % for PC2. This indicates therefore that the data were highly correlated and could be conveniently represented by these two principal components without consequential loss of detail. A plot of the principal components (Figure 2) showed that the 38 field sampled could be regrouped into about eight (8) homogeneous groups. The figures represent the listings of fields remain the same as listed in Table 1. From this Figure, it could be observed that the sizes of the groups varied enormously, from just one plot in Group IV, 2 plots in Groups III, V and VII, 5 plots in Group II to 13 plots in Group I.

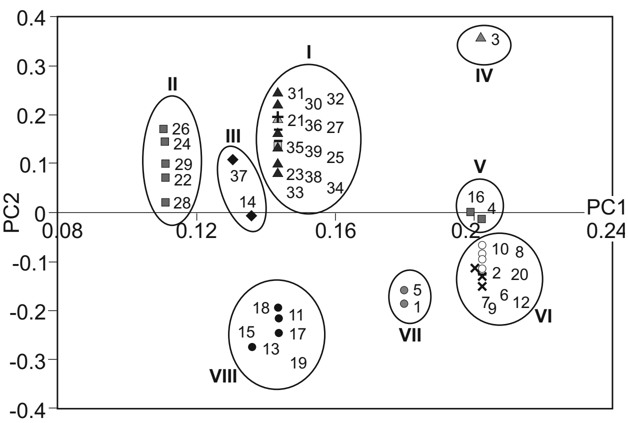

Figure 2:

Circle of correlation coefficients

A closer examination of plots that were judged similar following the analysis of principal components revealed that these grouping seemed to be dependent on the location of the fields, probably because this parameter could inadvertently encompass characteristics like the average farm size (as earlier indicated), the annual rainfall, the altitude and slope of fields, the composition of the soils (in terms of clay content, moisture content and soil depth) as well as the other soil characteristics (surface, gravels, colour, and parent material).

A firm was obligatorily in the same climatic zone, should constitute a homogeneous lot and be referenced to a nearby meteorological station. The different FSUs were then progressively determined following the soil criteria: clay content for the cationic exchange capacity (CEC) and water retention capacity, the base rock for the mineral composition, as well as the slope for erosion. The plants do not intervene in the definition of the FSU since they could change and are already taken into consideration in the definition of the Primary Production Units (PPU). Based on similarities between the two classification systems (land evaluation and statistical analysis), three firms were identified based on the different rainfall levels: Firms A, B and C with rainfall more than 3 m, between 2.5 and 3 m, and close to 2 m respectively. From these, classes were defined with respect to the clay content, parental material (bed rock), and the slope of the fields. An alphabetical nomenclature was defined for the different FSUs based on the different existing possibilities for each of the 3 firms as shown in Table 2.

- Three classes for clay content: 15 to 20 % = I ; 20 to 35 % = II ; 40 to 50 % = III;
- Two classes for parent material: i = volcanic ; ii = Volcanic/basement complex ;
- Three classes for field slopes: 0 to 5 % = a ; 6 to 10 % = b ; > 10 % = c.

Table 2:
Farming Section Units (FSU) identified using the land evaluation method

Clay / Parent rock/ Slope	Clay / Parent rock / Slope	Clay / Parent rock / Slope
I / i / a = A	II / i / a = G	III / i / a = M
I / i / b = B	II / i / b = H	III / i / b = N
I / i / c = C	II / i / c = I	III / i / c = O
I / ii / a = D	II / ii / a = J	III / ii / a = P
I / ii / b = E	II / ii / b = K	III / ii / b = Q
I / ii / c = F	II / ii / c = L	III / ii / c = R

On the whole, 14 FSUs were obtained for the 38 plots evaluated – 6 for Firm A, 4 for Firm B and 4 for Firm C (Table 3). For the first firm (**Firm A** with rainfall > 3 m) of 13 plots in the Kumba north zone, 6 FSUs were defined: G (4), P (2), H (2), M (3), L (1) and B (1). For the second firm (**Firm B** with rainfall between 2.5 and 3 m) of 20 plots in the Kumba zone, 4 FSUs were defined: D (2), J (2), F (1) and G (1). For the third firm (**Firm C** with rainfall of about 2 m) of 19 plots in the Bombe – Banga Bakundu zone, 4 FSUs were defined: P (3), R (2), J (13) and L (1).

Table 3:
Farming Section Units (FSU) identified using the land evaluation method

Plot	Village	Clay content (%)	Parent material	Slope (%)	FSU
a). Firm A – Rainfall > 3 m					
12	Etam 2	20 – 35 (II)	Volcanic (i)	6 – 10 (b)	B
1	S. Ekombe	20 – 35 (II)	Volcanic (i)	0 – 5 (a)	G
9	Etam 2	20 – 35 (II)	Volcanic (i)	0 – 5 (a)	G
10	Ebonji	20 – 35 (II)	Volcanic (i)	0 – 5 (a)	G
16	Ebonji	20 – 35 (II)	Volcanic (i)	0 – 5 (a)	G
3	Etam 1	20 – 35 (II)	Volcanic (i)	6 – 10 (b)	H
7	Etam 1	20 – 35 (II)	Volcanic (i)	6 – 10 (b)	H
8	Ebonji	20 – 35 (II)	Volcanic/basement complex (ii)	> 10 (c)	L
5	S. Ekombe	40 – 50 (III)	Volcanic (i)	0 – 5 (a)	M
6	Etam 1	40 – 50 (III)	Volcanic (i)	0 – 5 (a)	M
20	Etam 1	40 – 50 (III)	Volcanic (i)	0 – 5 (a)	M
2	Ebonji	40 – 50 (III)	Volcanic/basement complex (ii)	0 – 5 (a)	P
4	Ebonji	40 – 50 (III)	Volcanic/basement complex (ii)	0 – 5 (a)	P

Plot	Village	Clay content (%)	Parent material	Slope (%)	FSU
b). Firm B – Rainfall between 2.5 and 3 m					
11	Mukonje	15 – 20 (I)	Volcanic/basement complex (ii)	0 – 5 (a)	D
14	Mabonji	15 – 20 (I)	Volcanic/basement complex (ii)	0 – 5 (a)	D
17	Mukonje	15 – 20 (I)	Volcanic/basement complex (ii)	> 10 (c)	F
19	Mukonje	20 – 35 (II)	Volcanic (i)	0 – 5 (a)	G
15	Mukonje	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
13	Mabonji	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
c). Firm C – Rainfall about 2m					
23	Bombe	40 – 50 (III)	Volcanic/basement complex (ii)	0 – 5 (a)	P
25	Bombe	40 – 50 (III)	Volcanic/basement complex (ii)	0 – 5 (a)	P
26	Bombe	40 – 50 (III)	Volcanic/basement complex (ii)	0 – 5 (a)	P
38	Bombe	40 – 50 (III)	Volcanic/basement complex (ii)	> 10 (c)	R
27	Bombe	40 – 50 (III)	Volcanic/basement complex (ii)	> 10 (c)	R
18	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
21	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
30	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
31	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
32	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
33	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
34	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
35	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
36	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
37	Bombe	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
22	Malende	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
24	Malende	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
29	Malende	20 – 35 (II)	Volcanic/basement complex (ii)	0 – 5 (a)	J
28	Malende	20 – 35 (II)	Volcanic/basement complex (ii)	> 10 (c)	L

4 Conclusions

Although multi-storey cropping systems have the capacity to absorb some risks associated with crop cultivation, much is still unknown about their functioning, performance and durability. The Nutmon ® software has been proposed in the literature for evaluating the nutrient status/flows and economic performance of mixed farms or systems. As a prerequisite to launching the software, however, there is need for soil characterization, geo-referencing of plots and eventual designation of constitutive farm section units (FSUs). This study was undertaken therefore, to validate, using some multivariate statistical tool, the expert systems used for the definition of FSUs and then constitute FSUs for some 38 multi-storey perennial crop based farm holdings in the humid forests of South West Cameroon (North and South zones of Kumba).

Two approaches were adopted for the definition of the FSUs, one based on the traditional land evaluation expert systems and the other on a statistical analysis of the collected data. The results of this comparative study showed that although the both systems were complementary, the results did not always completely converge owing to the differences in the choice of the nature and the magnitude of the criteria considered. Three firms were identified and these differed distinctly especially with respect to the average annual rainfall, and to lesser extents, the soils' clay content, soil parent material (bed rock) and the slope of fields. On fine-tuning all available information using the both approaches adopted, the 38 fields could be regrouped into 14 different FSUs of variable sizes. The results obtained here demonstrate the feasibility of complementing the traditional land evaluation technique with some multi-variate statistical analysis (principal components) to classify perennial crop based farming systems.

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