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Typologies of pineapple-based farming systems in Centre-Cameroon

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The high diversity in pineapple fields and farmers provide huge challenges in farm management in already dwindling pineapple production sector in the center region of Cameroon. A first step to overcome these production challenges is to manage the afore-mentioned diversity to a reasonable level without loss of detail and specific management interventions for each category or typology proposed. Field surveys were conducted in two pineapple producing areas in the center region of Cameroon (Awae and Bokito), with a view to collect data on pineapple farms and producers. Data collected was later subjected to multivariate analysis. 67% of farms variability was captured within 02 components: Investment, plant density, soil fertility, and input factors. Cluster analysis captured 03 pineapple farming systems typologies: (1) subsistence poor resource smallholder farmers; (2) market oriented, low to medium resource farmers; and (3) market oriented, high resource large-scale farmers, representing 62.1, 32.1 and 5.8%, respectively of farms. The unexplained 33% of variability between farms was attributed to biophysical characteristics of pineapple producing area. Pineapple production in the center region of Cameroon demonstrates enormous potential for improvement. Understanding these bio-physical production potential is a satisfactory approach for pineapple production intensification.

Key words: Farming system, smallholder farmers, typology, pineapple.

INTRODUCTION

Pineapple (*Ananas comosus* (L.) Merr.) is a plant valued for its fleshy and succulent fruit. It is cultivated for economic interest and is the second most exported fruit from Cameroon to European zone (Ngo Bogmis et al., 2017). In Cameroon, the coastal, south, and central areas constitute the three main pineapple production regions (INS, 2017). In the Centre region of Cameroon for example there are two major pineapple production basins; Bokito and Awae. Bokito's fruits commonly called"Bafia pineapple" are more appreciated (unofficial information) by consumers in terms of quality (taste).

Generally, pineapple yield in Cameroon (34.9 $t.ha^{-1}$) is considered to be low compared to that of Ghana (61.9 $t.ha^{-1}$), Benin (61.0 $t.ha^{-1}$) and Ivory Coast (59.4 $t.ha^{-1}$)

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Table 1. Major soil groups of Bokito and Awae localities.

Locality	Soil group		
	USDA	**WRB**	**CPCS**
Bokito	Kandiustults	Dystric Acrisols (Gleyic)	*Slightly or moderately desaturated and hydromorphic ferralitic soils*
	Kandiustults	Dystric Acrisols	*Ferralitic soils weakly or moderately desaturated*
	Paleustults	Dystric Nitisols	*Ferralitic soils strongly desaturated*
Awae	Haplustox	Haplic Ferrasols	*Ferralitic soils strongly desaturated*

USDA: United State Department of Agriculture, WRB: World References Bases, CPCS: *Commission Pédologique de Cartographie des Sols*.
Source: Vallerie (1973); Jagoret et al. (2012); Jones et al. (2015).

(FAOSTAT, 2021), may be because pineapple production is more for local consumption than for exportation. Exportation of pineapple fresh fruits from Cameroon to Europe has decreased for more than 90% during the last ten years (FAOSTAT, 2021) resulting to a reduction of its contribution to the gross domestic product (GDP). For the last ten years, the decline in yield in the Centre region of Cameroon was estimated to about 51% (INS, 2017). In addition, the quality (shelf life, acidity, and taste) of pineapple has been unsuitable for pineapple stakeholders (Ngo Bogmis et al., 2017). In order to maintain quality and/or to improve the production of pineapple in this region, producers have extended their cultivated area, despite the negative consequences it has on the environment (Gillet et al., 2016).

The pineapple based-farming systems is dominated by small-scale family farms (Yengoh and Ardö, 2014) which are heterogeneous in nature, thereby rendering the identification of production constraints and the formulation of recommendations difficult, costly and time-consuming (Alvarez et al., 2014). Farm typology helps to highlight similarities and differences between different farms, identifies common constraints as well as areas for recommendations (Alvarez et al., 2014, 2018). It becomes important to look at the socio-economic characteristics of the producers, production constraints, and the typology of their production systems in order to design best management interventions. The aim of this work was to identify pineapple farming system typologies required to guide management decisions for optimal production.

MATERIALS AND METHODS

Location of the study area

This study was conducted in the Centre region of Cameroon in the Bokito and Awae localities, situated in a forest-savanna transition agro-ecological zone characterized by a bimodal rainfall pattern (Jagoret et al., 2012). The Bokito locality situated at Latitude 4.30° N and Longitude 11.10° E, with an elevation of 310 to 1212 m above sea level, has a mean annual rainfall between 1300 and 1400 mm and a mean annual temperature of 25°C (Jagoret, 2011). It has Dystric Nitisol and Dystric Acrisols (Gleyic) (Table 1) (Jones et al., 2015).

The Awae locality situated at Latitude 3.35° N and Longitude 11.36 E with forest vegetation (Tchindjang et al., 2019), has an elevation of 544 to 1168 m above sea level, mean annual rainfall fluctuating between 1500 and 2000 mm and mean annual temperatures between 23 and 25°C (Tchindjang et al., 2019). Soils of the Awae locality are Haplic Ferralsols (Jones et al., 2015).

Data collection

The study was carried out through a field survey that involved a face-to-face interview using a structured questionnaire, designed to capture socio-economic information of the producers (age, sex, main activity, mode of land acquisition, years in cultivation, household information), routine farm management practices (soil preparation, seed acquisition, sowing density, type of sowing, variety used, beginning time of cultivation operations, fertilization and amendment), plant protection (products and frequencies), growth regulator (type and period of application), crop association, crop rotation), harvesting and post-harvesting operations. Data for the afore-mentioned operations were collected using the open data kit (ODK) installed on smartphones. The questionnaire was administrated through ODK alongside pictograms for variety and disease identification.

Sample size and sampling procedure

The sample size was determined based on the percentage of farm households producing pineapples in the Bokito locality by Dagnelie's Equation 1 for a population of an unknown size according to Sossa et al. (2014), was used:

$$n = Z_{\alpha}^{2} \times P(1-P)/d^{2} \quad (1)$$

where n = sample size; Z = critical value of the normal distribution at the required confidence level; p = proportion of households producing pineapple in Bokito locality; d=maximum allowable error 1% ≤d ≤ 15%.
For this work α = 5%, Zα = 1.96 and d = 9.8%. The proportion of households producing pineapples in the Bokito locality was determined after pre-surveys to be 125 producers in 8 villages. It was set at 50% and 6 of the 8 villages were selected. For these criteria n = 100 individuals were surveyed in the six selected villages. For the Awae locality, the sample size was calculated using Yaro Yamane's Equation 2 for a population of a known size (Oribhabor and Anyanwu, 2019).

$$n = N / [1 + N(e)^{2}] \quad (2)$$

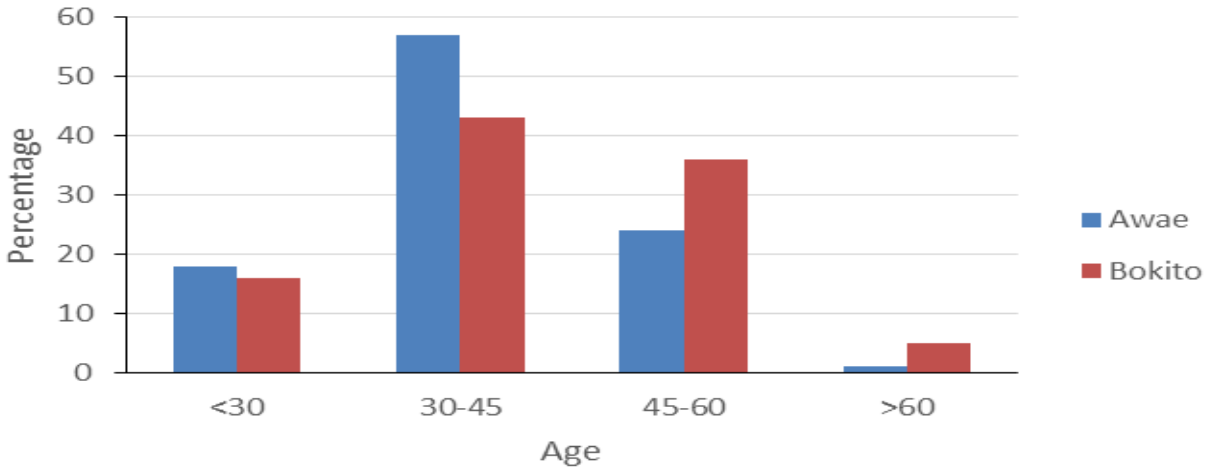

Figure 1. Age of pineapple farmer in center region of Cameroon
Source: Author

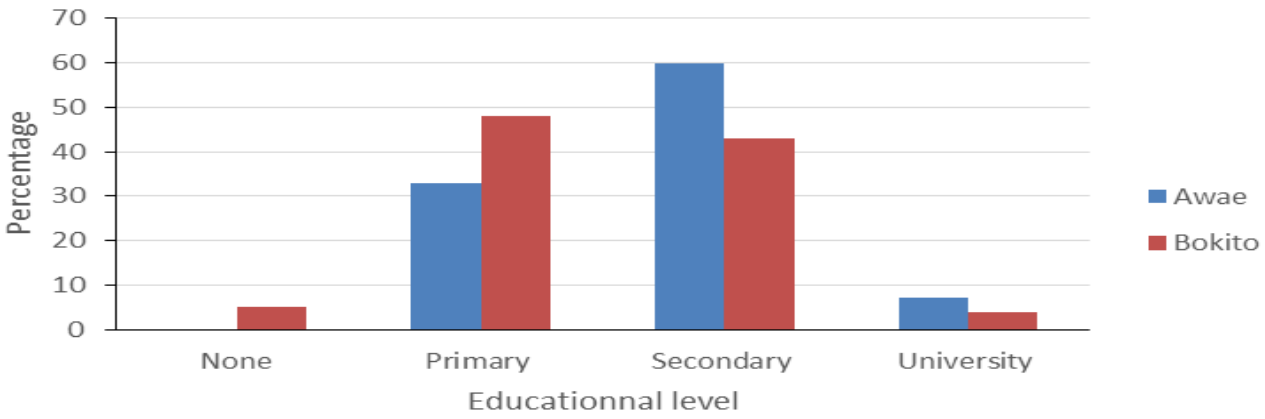

Figure 2. Educational level of pineapple farmer in center region Cameroon.
Source: Author

where n = sample size; N = population size; e = allowable error.

For this work e = 9.8%; N = 291 (Ministry of Agriculture and Rural Development). Using criteria n = 76 individuals were surveyed in the Awae locality.

The questionnaire was administered to the respondents using the simple random sampling method and snowball effect in each of the locality and for each of the production zones identified.

Data processing and analysis

Descriptive statistics (frequency, mean, standard deviation) were used to characterize the pineapple producers. The typology of the production systems was achieved by factor analysis of mixed data (FAMD) followed by hierarchical cluster analysis (HCA) (Alvarez et al., 2018; Zoma-Traoré et al., 2020). These multivariate techniques have the advantage of accounting for the complexity of agricultural systems by considering many dimensions and highlighting some dimensions that are more explanatory of the diversity of the farms (Alvarez et al., 2014). The data processing for the multivariate analysis followed the procedure described by Alvarez et al. (2014).

RESULTS

Socio-economic characteristics of pineapple producers

Pineapple production in the Bokito locality is organized in villages and carried out by the indigenes. These producers are dominated by individuals aged between 30 and 45 years (43%), followed by individuals aged between 45 and 60 years (36%) (Figure 1). Pineapple production is mostly carried out by women (66%), 51% of whose households have 6 to 10 members (Figure 2). Agriculture is the main activity of these producers, with pineapple cultivation ranking second and/or another place in 87% of households. 95% of pineapple production is for sale and consumption and 80% of these producers are exploiting family land obtained through inheritance. There is social constraint in land, probably these

Table 2. Socio-economic characteristics of pineapple producers in Bokito and Awae localities.

Variable	Frequency (%)	
	Awae (n=76)	Bokito (n=100)
Sex		
Female	1.0	66.0
Male	99.0	34.0
Household size		
≤5	63.0	41.0
6-10	36.0	51.0
11-13	1.0	8.0
Main activity		
Agriculture	83.0	93.0
Trade	10.0	0.0
Other	7.0	7.0
Agricultural training		
Yes	7.0	0.0
No	93.0	100
Purpose of pineapple cultivation		
Consumption	0.0	1.0
Sale	97.0	4.0
Sales and consumption	3.0	95.0
Place of pineapple in farming activities		
First	100.0	13.0
Others	0.0	87.0
Socio-professional group		
Yes	0.0	18.0
No	100.0	82.0
Farm size (ha)		
<2	17.0	97.0
2-5	62.0	1.0
>5	21.0	2.0

Source: Author

indigenes refuse to sale or rent land to another ethnicity group (Table 2 and Figure 4). In addition, 97% of pineapple producers operate on farm size ≤ 2 ha (Table 2).

In the Awae locality, there is a zonal production usually identified by the name of the village with producers coming from the city and non-natives (Figure 4). These producers are dominated by individuals aged between 30 and 45 years (57%), followed by individuals aged between 45 and 60 years (24%) with most of the producers being men (99%). 63% of these producers have households that range from 1 to 5 members and 82% of these producers have agriculture as their main activity. Pineapple is the main crop for all the producers, with production oriented towards marketing and 76% of the producers obtained the cultivated fields by renting in (Table 2 and Figure 1). In addition, 41% of the producers this locality operate on farms ≤ 2 ha (Table 2). Pineapple production in Bokito locality started a few years ago before Awae locality (Figure 3). But in two areas producers did not receive agricultural training in pineapple cultivation, although these farmers are literate. Absence of socio-professional groups of pineapple producer reduces facility to cope with training.

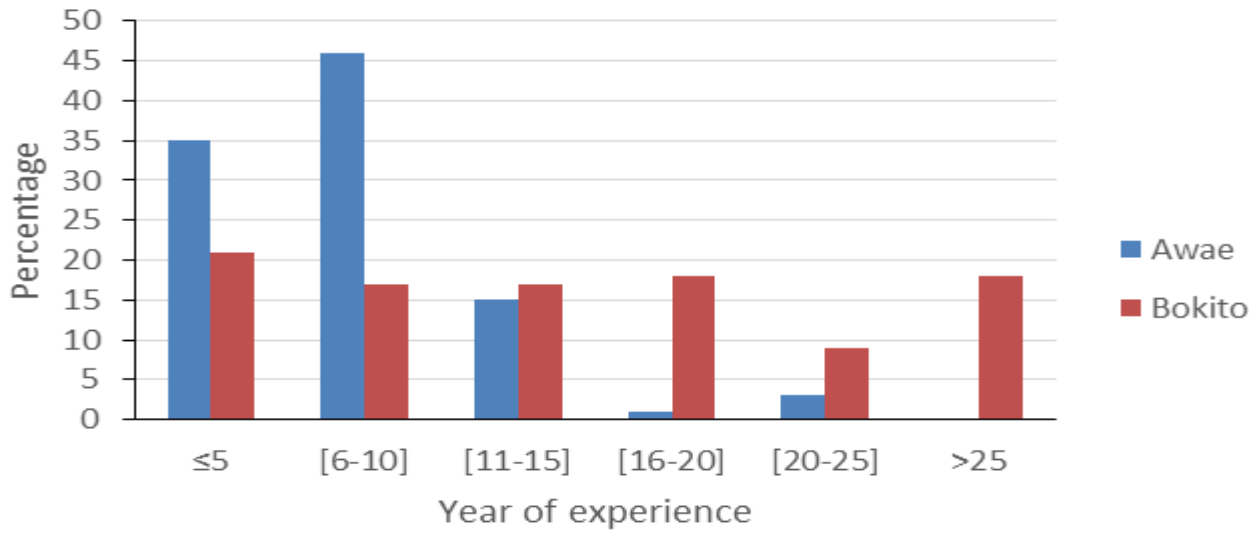

Figure 3. Experience of pineapple producer in center region of Cameroon.
Source: Author

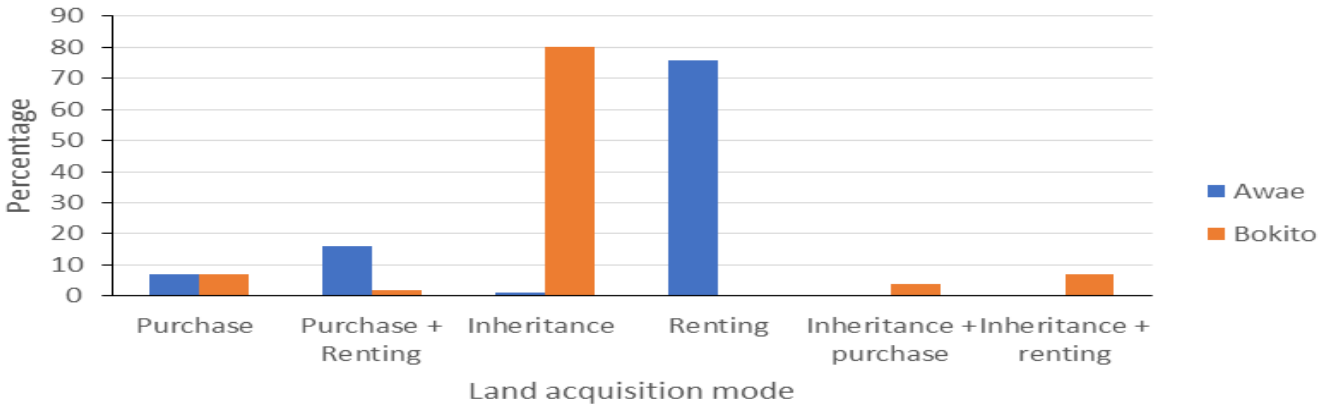

Figure 4. Dominant mode of land acquisition in Bokito and Awae localities
Source: Author

Farm management practices

Soil preparation for pineapple sowing in the Bokito locality is done in four modalities with flat ploughing (58%) as the dominant practice, follow by ploughing and ridging (40%) this second practice dominate the soil with low infiltration and/or flooding condition in part of growing cycle. Production is done both in the dry and rainy seasons, at extremely low plant density in a random configuration (Table 3). In both localities planting material is gotten from old fields and neighboring producers also, all available shoot sizes are used (Table 3). Pineapple production in the Bokito locality is dominated by the Smooth Cayenne cultivar (66%), followed by Abacaxi (24%). However, the widespread practice comprises a mixture of different cultivars in the same field, also planting density in this locality is not optimized (Table 3). These productions remain traditional and producers' knowledge growth with time and difficulties face in the production.

Contrarily, in the Awae locality, soil preparation is done by minimal tillage (Table 3). Sowing is done in both seasons with planting material obtained from old fields and other producers in a double row configuration. Production in this locality is dominated by two cultivars, smooth cayenne, and red Spanish in monoculture systems, plant density remains low but high for that of Bokito (Table 3). These plants densities are obtained by more than eighteen configurations; this implies that no plant density is recommended in Awae and Bokito localities. The reason is that pineapple production was abandoned for long period in Cameroon. The dominant

Table 3. Characteristics of pineapple-based farms in the Bokito and Awae localities.

Variable	Frequency (%)	
	Awae(n=76)	Bokito (n=100)
Soil preparation		
Minimal tillage	100.0	-
Ridges	-	1.0
Mound	-	1.0
Flat ploughing	-	58.0
Ploughing + ridging	-	40.0
Seeds type		
Slip	100.0	87.0
Slip+ crown	0.0	13.0
Cultivars		
Abacaxi	0.0	24.0
Smooth cayenne	51.0	66.0
MD-2	0.0	5.0
Sugar loaf	0.0	2.0
Queen	0.0	1.0
Red Spanish	49.0	2.0
Types of seed rows		
Unique	1.0	0.0
Double	99.0	0.0
Random configuration	-	100
Plant density		
≤10000	0.0	100
25000,35000	19.0	/
35000,45000	47.0	/
45000,55000	30.0	/
55000,65000	4.0	/

Source: Author

acquisition mode and absence of phyto-sanitary treatment of planting material underline high level of propagation of disease and pest.

Farm inputs

Pineapple production in the Bokito locality remains traditional because is done without the use of synthetic inputs like fertilizers and pesticides; flowering was not induced by used of growth regulator. In this case proportion of marketable pineapple fruit depend on climatic condition and other factors that influence flowering of pineapple, sale of pineapple fruit is not programmed by producer of Bokito locality (Table 4). However, in the Awae locality, production is conventional, based on the use of synthetic inputs (mineral fertilizers, pesticides) and growth regulators (Table 4). Flower induction and de-greening are widespread operations for producers in the Awae locality (Table 4). Fertilization is often diverse, K/N ratio fluctuates between 0.99 and 4 and shows that fertilization of pineapple is not well known by pineapple producers. The most mineral fertilizers used are Urea (46%), potassium sulfate K_2SO_4 and compound fertilizer NPK 20-10-10. The use of farm input such as growth regulator shows that Awae pineapple producers programme their flow of sale based of prices in knowledge of markets.

Pineapple-based cropping systems

The producers in the Bokito locality practice mixed intercropping with pineapple like companion crop. These mixed intercropping systems are done to insure family food and livelihood condition into the years. The base

Table 4. Agro-technical management of pineapple production in the Awae and Bokito.

Variable	Frequency (%)	
	Awae (n=76)	Bokito (n=100)
Mineral fertilization		
Yes	100.0	2.0
No	0.0	98.0
Disease management		
Yes	12.0	2.0
No	88.0	98.0
Pest management		
Yes	78.0	2.0
No	22.0	98.0
Weeding		
Manual	0.0	98.0
Manual+ chemical	100.0	2.0
Floral induction		
Yes	100.0	0.0
No	0.0	100.0
De-greening		
Yes	95.0	0.0
No	5.0	100.0

Source: Author

crops in these systems are cassava, maize, yam, potato, groundnut, plantain, egusi, cocoyams and cocoa. However, 33% of these producers practice fallowing as a soil fertility management strategy. Soil fertility restoration remains low because fallowing time is low; this situation led to soil fertility depletion and decreases of the yield of all crops in systems (Table 5).

In the Awae locality, 2/3 of pineapple producers practice mono-cropping and only 1/3 practice mixed cropping with 2 associate crops (Table 5). However, mixed cropping is done along the farm borders with banana remains the associated crop (dominant system), and on alternate rows with maize and chili pepper. In these associations, pineapples are the base crop, and the companion crops are banana, maize and chili pepper (Table 5). The companion crops are intended for sale and direct consumption by the producer's household (Table 5).

Profitability of pineapple production

Pineapple production in Bokito locality is very low and reflects the cropping systems and importance of this crop for farmers in this locality. Selling prices of pineapple fruit in this locality are very high between 265 and 500 because most producers sell their fruit directly in the market. Principal expenditure come from soil preparation (clearing and ploughing) and their costs were reducing when producers are members of informal groups of work. Income generated by pineapple cultivation is not the main source of income for pineapple producers in the Bokito locality (Table 6).

As compared to Bokito, the level of investment in pineapple production in the Awae locality is 14 times higher (Table 6). Consequently, these producers obtain a sale's income 19 times greater than that of Bokito producers. Pineapple is, therefore, a crop of primary economic importance for producers in the Awae locality (Table 6). Pineapple production in Awae locality is a business for all producers. It contributes to employment of local rural population, and it is the most sources of pineapple fruits for the center region of Cameroun. This high investment capacity is not used in optimal manner because there is extensive pineapple production.

Pineapple production systems

Result of FAMD provides information that captured

Table 5. Pineapple-based cropping systems in Awae and Bokito localities.

Variable	Frequency (%)	
	Awae (n=76)	Bokito (n=100)
Crop type		
Pure	68.0	0.0
Mixed	32.0	100.0
Purpose of the associated crop		
Sales and consumption	54.0	86.0
Consumption	46.0	1.0
Sales	/	13.0
Pineapple status in association		
Companion crop	0.0	93.0
Base crop	100.0	7.0
Rotation		
Yes	4.0	25.0
No	96.0	75.0
Fallow		
Yes	39.0	33.0
No	61.0	67.0

Source: Author

Table 6. Investments and income generated by pineapple cultivation in the Awae and Bokito localities.

Variable	Frequency (%)	
	Awae (n=76)	Bokito (n=100)
Number of marketable fruits		
≤10000	4.0	100.0
10000-25000	12.0	-
25000-35000	74.0	-
35000-45000	10.0	-
Place of sales		
Farmgate	96.0	37.0
Market	1.0	63.0
Farmgate-markets	3.0	-
Expenditure (CFA franc)		
≤1000000	1.0	100.0
1000000-2500000	55.0	-
2500000-3500000	41.0	-
3500000-4500000	3.0	-
Income (CFA franc)		
≤1000000	/	100.0
2500000-3500000	4.0	-
3500000-4500000	24.0	-
4500000-5500000	54.0	-
>5500000	18.0	-

Source: Author

Table 7. Result of FAMD factors loading.

Parameter	Dim.1	Dim.2
Farm size (ha)	0.51	0.74
Number of associate crops	-0.75	-0.03
Fruit harvest number	0.97	0.03
Yield kg.ha^{-1}	0.98	0.04
Plant density	0.97	0.08
Expense CFA franc	0.96	-0.13
Income CFA franc	0.98	-0.03
N kg.ha^{-1}	0.76	-0.38
K_2O kg.ha^{-1}	0.86	-0.04
P_2O_5 kg.ha^{-1}	0.80	-0.25
K/N ratio	0.73	0.56
Insecticide (kg)	0.67	-0.24
Herbicide (kg)	0.74	-0.21
Eigenvalue	13.5	1.8
Percentage of variance	58.9	8.19
Percentage of cumulative variance	58.9	67.1

Source: Author

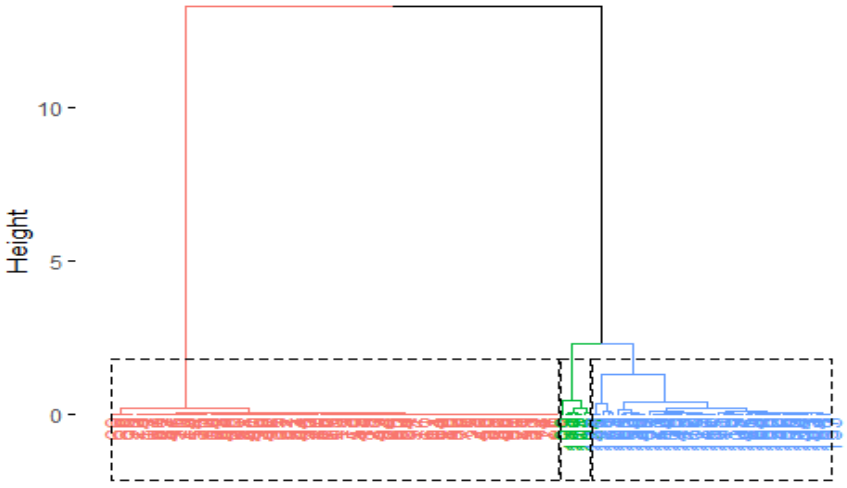

Figure 5. Distinctive cluster of pineapple farmer in the Centre region of Cameroon.
Source: Author

67.0% of variability within farm. Investment factor, plant density and soil fertility level are the first factor that creates diversity within farms and it explains 58.9% of variation. Farms size is the second and third factors that account for 8.1% of variability within farms, respectively (Table 7). There are twenty-three variables with 6 categories and 13 continuous (Tables 7 and 8). These key variables with the first 03 dimension of FAMD were used to perform HCA. Result of HCA showed 03 distinctive farming systems type (Figure 5) and the characteristics of each type are summarized in Table 8.

Type 1 refers to subsistence resource-poor smallholder farmers, where women represent 65.9% of such producers and sell only a surplus of pineapple production to support household food needed. Mixed cropping system is the dominant practice in this type. Also, this system is mostly encountered in Mbam and Inoubou division and represents 62.1% of pineapple producers (Table 8).

Type 2 refers to as market oriented small-to-medium resource farmers. Rent (86.4%) is the dominant mode of land acquisition, typically new producers with little

Table 8. Characteristics of pineapple-based production system typologies in the Awae and Bokito localities.

Variable	Type		
	1	2	3
Quantitative			
Number of associated crops	3.0±1.0[a]	0.3±0.6[b]	0.3±0.4[b]
Farm size (ha)	0.30±0.23[a]	3.49±4.04[b]	11.8±5.8[c]
Fruit harvest number.ha^{-1}	810±580[a]	31005±5823[c]	33333±2624[b]
Plant density	1508±1131[a]	39942±5322[c]	47526±5783[b]
Insecticide kg	0±0[a]	7.67±6.19[b]	6.78±5.00[b]
Herbicide kg	0±0[a]	13.2±9.4[b]	14.9±16.9[bc]
N kg.ha^{-1}	0±0[a]	340.4±208.3[b]	117±31[c]
K_2O/N ratio	0±0[a]	1.0±0.4[b]	2.8±0.9[c]
P_2O_5 kg.ha^{-1}	0±0[a]	39.1±21.2[b]	20±0.6[c]
K_2O kg.ha^{-1}	0±0[a]	290.0±160.3[b]	311.0±73.1[bc]
Yield t.ha^{-1}	1.6±1.2[a]	38.6±4.2[b]	40.3±3.2[b]
Expense CFA franc.ha^{-1}	83540±57031[a]	2759459±424556[bc]	2466667±74535[c]
Income CFA franc.ha^{-1}	196175±174886[a]	5305405±635416[b]	5416667±533593[b]
Qualitative			
Land acquisition mode	Heritage (100)	Rent (86.4)	Purchase and Rent (100.0)
Fertilizer uses	No (100)	Yes (100)	Yes (100)
Production objective	Sale and Consumption (97.5)	Sale (97.2)	Sale (100.0)
Pesticide uses	No (98.9)	Yes (94.3)	Yes (100)
Labor type	Familiar (47.5), Familiar and Hired (52.5)	Hired (100)	Hired (100)
Gender	Women (75.0), Men (25.0)	Men (100.0)	Men (100)
Percentage of representation	62.1	32.1	5.8

For quantitative variables, the results are in the form of mean ± standard deviation; *P<0.05, **P<0.01, ***P<0.001.
Source: Author

technical knowledge about pineapple cropping and some with increasing knowledge over time in pineapple cropping. These producers are second most important group representing 32.1% of pineapple producer. Pure cropping systems, with synthetic chemical input and hired labor are dominant in this system. However, mixed cropping (banana in the border of pineapple field) exists in these systems, pineapple growth with normal density in pure. Type 3 representing 5.8% of producers, is referred to as market oriented high resource large-scale farmers with 100% of hired labor in pure conventional cropping systems (Table 8). Between type 2 and 3, no difference in yields is observed. This implies that farmers produce without good knowledge of biophysical constraint of their environment and also anterior knowledge of management of pineapple field.

DISCUSSION

Investment factors, plant density and soil fertility level factor accounted for 58.9% of farm variability agree with the findings of Tittonell et al. (2005) and Tittonell (2008). In the centre of Cameroon, three distinctive farming systems were identified. The major differences in these farming systems type stem from gender, labor force, farm size, the number of crops in the field, quantity of input use and land acquisition (Table 8). These key variables agree with findings of many authors (Castella et al., 1994; Bidogeza et al., 2009; Alvarez et al., 2014; 2018; Bhattarai et al., 2017; Kumar et al., 2019; Musafiri et al., 2020; Zoma-Traoré et al., 2020; Kaur et al., 2021). The first type, subsistence resource-poor smallholder farmer are in continuity with the findings of Yengoh and Ardö (2014). The dominance of women in type 1 explains the high proportion of small farms (0.30±0.23 ha), low pineapple production, the position of pineapple among the crops produced and farm income. The labor force, working time and availability of capital are actual constraints for these women confirming the findings of Tambi et al. (2017). In addition, these findings are in line with that of Fonjong et al. (2010) who explained that women inherited land from their husbands and/or parents, and the size of the cultivated fields depends on the family head's decision and vision. Moreover, women do not have technical training on the pineapple production because of their multiple activities and the position in the traditional society (Fonjong et al., 2010;

Fon, 2011; Tambi et al., 2017). Finally, production conducted by women is oriented towards household consumption (mixed cropping) as well as the stabilization of household income, which is very often different from that of men (Tambi et al., 2017).

The traditional management of the cultivated fields without mineral fertilization and synthetic pesticides is in accordance with assertion of Abate et al. (2000). The non-use of chemical fertilizer is explained by the search for independence in the production activity (Dossa et al., 2018). The search for solutions adapted to the orientation of agricultural production carried out by women is a priority for the improvement of the living conditions of households.

Mixed cropping practiced by producers in type 1 (mostly Bokito locality) is in accordance with the finding of Uriza-Ávila et al. (2005). Combination of crops in mixed cropping is not in line with good soil fertility management practices (Bedoussac et al., 2015; Emma-Okafor et al., 2018; Ajayi et al., 2020). These cultivated crops include roots, tubers, cereals, and fewer vegetables. However, the improvement of the soil fertility status in mixed cropping systems is achieved by associating leguminous with other crops (Bedoussac et al., 2015; Emma-Okafor et al., 2018). Also, gaps in the lack of disease and pest management strategies in these traditional management systems reduce the productivity of the farms. However, mixed cropping systems offer better environmental management than pure cropping systems and has advantages for sustainable production (Kremen et al., 2012; Kremen and Miles, 2012; Gebru, 2015). For these farmers research of an equilibrium between density of food crops and pineapple (cash crop) in the field to capture a better return lead to amelioration of her living condition (Uriza-Ávila et al., 2005). A great challenge for these farmers is maintaining a good level of soil fertility to support sustainable production over time. Management of soil fertility in intercropping is not well documented at this time, especially for intercropping of pineapple-root and tuber, pineapple-cereal. Integrated soil fertility management (ISFM) becomes a good means to improve productivity and sustainability of these types of farms. This approach requires good knowledge on soil quality, precisely understanding of cultural practice in space and time dimension and nutrient need by each crop in systems (Vanlauwe et al., 2015). Adapted mechanization is another point that could help these types of farmers to achieve their goals (Sims et al., 2012). Governmental institutions and NGOs could undertake training facilities to ameliorate knowledge of farmers on good management practice related to their constraints (Mgendi et al., 2021). The dominant mode of land acquisition (inheritance) shows that it is possible to implement long-term management strategies like agroforestry and conservation agriculture in cultivated fields (Abdulai et al., 2011).

Type 2, market oriented, low to medium resource farmer and type 3, market oriented, high resource large-scale farmer, are not in continuity with the findings of Yengoh and Ardö (2014). Who emphasized that Cameroonian agricultural production is done on small areas with a low level of farm input. Male dominance in pineapple production in these two type is consistent with the observations of Sarpong et al. (2017). Men focus their production on marketing of growing cash crops (Fonjong et al., 2010; Harman et al., 2015; Sarpong et al., 2017). Pineapple production in type 2 and 3 (mostly found in Awae locality) is conventional (Darnaudery et al., 2018), dominated by blanket fertilization recommendation. For these practices, the K/N ratio is below or above the recommended dose and leads to a reduction in crop yield and fruit quality (Sossa et al., 2017; Djido et al., 2021). The low planting density contributes to low yields (de Souza et al., 2019; Sanya et al., 2020). Djido et al. (2021) showed that, high planting density does not influence the weight of the fruits. This observation is contrary to the assertion of producers; planting densities are reduced to obtain larger fruits. Poor disease management is another factor in yield reduction. Producers rent the land for two to three production cycles and then abandon it and migrate to new land. This leads to a reduction of forest areas and a pronounced environmental degradation (Gillet et al., 2016). This also reflects the failure of their production techniques to maintain productivity, despite the use of mineral fertilizers. However, Sossa et al. (2015) showed that these cropping systems affect the physical quality of the soil after 10 years and the chemical quality after 7 years of continuous use. For this shifting cultivation system, the abandonment of cultivated fields is not only due to soil fertility decline, but pathogens also harbored in the soil (Rohrbach and Johnson, 2003). The technical level of producers in type 2 is low and typical of African pineapple producers (Djido et al., 2021). 32.1% of producers in the Awae locality belong to the second production system. For this system, the K/N ratio of 1.04±0.4 indicates an inferior quality of marketed fruit explaining consumers complaints in this locality (Djido et al., 2021). Also, labor force used in pineapple farm is not qualified and same farmer have not received training in management of pineapple field. This led to lack of success of some field operation, and shows that pineapple is still a neglected crop for a long period in Cameroon. Income returns per hectare, in type 2 and 3 are not significantly different, showing that knowledge of management techniques, input use, and labor force are archaic. High resource pineapple producer does not take pineapple production like an enterprise. In fact, pineapple production rest extensive, with increasing production surface for augmented production, while yields remain the same. Although high investment level is one key for use in modern management techniques and acquired training labor force (Bidogeza et al., 2009), there are inappropriate management for these high resource pineapple farmers. In favor to satisfaction of the present and increasing demand, intensification must take place in

pineapple production systems in center Cameroon. The above 33% of variability not capture by socioeconomic and management factors underline that biophysical factor is another important factor explaining farms' variability (Banerjee et al., 2014). Appreciated biophysical potential and underlined production constraints become a key step intended to design appropriate management of each pineapple farm types (El Sayed Said et al., 2020).

Conclusion

Investment factor, plant density and soil fertility and input factor are the factors explaining 67% of diversity of pineapple farm in Center-Cameroon. Three types of pineapple farming systems were identified based on these factors. Biophysical parameters explain 33% of variation between farms' groups. Improvement of pineapple production must consider a good determination of biophysical potential, evaluation of actual soil fertility management, and specific integrated approach for each farm type, such as integrated soil fertility management, training of producers on modern good pineapple cropping practice, and facilities of funding acquisition.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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