

SUSTAINABILITY PROSPECTS FOR THE SMALLHOLDER MAIZE FARMING SYSTEMS IN NORTHERN CÔTE D'IVOIRE

ABSTRACT

Aims: In Côte d'Ivoire, as in many other regions of sub-Saharan Africa, the sustainability of agricultural practices has become a crucial challenge to feed a growing human population. The study was aimed to contribute to better targeting of development efforts on sustainable intensification of maize cultivation, through the diagnostics of smallholder farming practices.

Study design: The study was designed as a cross-sectional survey, involving 80 individual farmers, who were selected in four locations (20 per location) according to their involvement in maize cultivation.

Place and Duration of Study: The study was conducted in the largest maize production and consumption area in the northern region, between March and September 2022.

Methodology: The investigation was focused on the social characteristics of farmers, agronomic characteristics of cultivation systems and on the production constraints.

Results: The results showed that the maize growing farmers were natives (98.00%) and men (99.00%), without formal education (74.99%). Maize-based cultivations varied, with a prevalence of intercropping systems (53.16%). It is grown on a land area of 5 to over 11 hectares, with common uses of improved varieties, chemical fertilizers and pesticides. The production is impaired by poor use of agricultural inputs, poor resource endowments of farmers and fluctuating prices, resulting in low yield and profitability (132 to 768 Euro ha⁻¹).

Conclusion: Attempts to sustain productivity can be geared towards sound agronomic principles, including implementation of Integrated Pest and Disease Management, minimal tillage and soil mulching, application of manure (legume residues) and moderate fertilizer rates, combined with strengthening farmers' knowledge and reliable marketing chains.

Keywords: Maize; Cropping systems; Production constraints; Sustainability; Côte d'Ivoire.

1. INTRODUCTION

Building a resilient and sustainable agriculture has become a core challenge to meet the growing human population food demand in sub-Saharan Africa [1]. Most of the agricultural production is ensured by smallholder farmers with poor resource endowments, which account for 80% of all farms [2]. Smallholder farming systems contribute about 90% of agricultural

production and 27% of Gross Domestic Product (GDP) growth, and provide employment to 60% of the population [1]. In Côte d'Ivoire, as in many other regions of sub-Saharan Africa, the intensification of subsistence agriculture such as maize cultivation is crucial to sustain food security and alleviate poverty [3]. Maize is ranked second as cereal crop, with an annual production of 1.1 million tons, and is valued for human consumption over years [4; 5]. The cultivation is widespread in all agro-ecological zones, but is mostly grown in the northern region, where it serves as the main staple food and a source of income generation for rural communities [6]. The grains (either fresh or dried) are consumed under various dishes for their nutritional value, which stems from high contents of starch, proteins, minerals, vitamins and other energetic nutrients [7; 8].

The smallholder maize farming systems often result in low yields (0.6 to 0.7 tons per hectare), as a result of biophysical and socio-economic constraints that include the implementation of unsustainable agricultural practices [9]. Sustainable agriculture refers to a system approach to food and feed production that promotes the health of soils, ecosystems and people [1]. This approach integrates social, environmental, and economic interests of the cropping systems. Unsustainable agricultural practices, more than leading to natural resources degradation (soils depletion and ecosystems pollution) and to some yield gaps, have negative impacts on farmers and consumers. Therefore, the understanding of current farmers' practices is capital to a better targeting of the research efforts on agricultural sustainability. Such an attempt can help alleviate production constraints and develop remedial measures to enhance resilience and productivity. The objective of this study was to contribute to the orientation of development efforts on sustainable intensification of maize cultivation, through the diagnostic of the smallholder farming practices.

2. MATERIAL AND METHODS

2.1. Material

2.1.1. Study area

The socio-economic survey on maize cultivation systems was carried out in four villages of the ecological zone of Korhogo, during the 2022 (April to September) cropping season. This region is located in the North of Côte d'Ivoire and is among the largest maize production and consumption areas. It is covered by a tropical climate, with a rainy season starting from April to November, and a dry and warm period from December to March. The annual rainfall ranges from 900 to 1600 mm and the temperature from 24 to 33 °C, with an average humidity of 20% [8]. The natural vegetation is composed of shrubby and herbaceous savannah, and the soils dominantly belong to the group of Ferralsols.

2.1.2. Plant and technical material

The biological material was consisted of maize and associated crops. The technical material consisted of survey sheets with a semi-structural questionnaire and interview recording devices.

2.2. Methods

2.2.1. Methodology of investigation

2.2.1.1. Target population

The study involved 80 individual maize farmers from four locations in the agro-ecological zone of Korhogo. These farmers were selected on the basis of their experience in maize cultivation. A prior survey (background research) was conducted in the study area with the collaboration of the technical support structures for the selection of localities and farmers and for the elaboration of the questionnaire.

2.2.1.2. Socio-economic survey

A cross-sectional socio-economic survey was conducted in the agro-ecological zone of Korhogo, during the cropping season of April to September 2022. This survey was implemented in four locations (Madoukaha, Tahouara, Bemavogo and Siolokaha), selected on the basis of the significance of maize production activities and their geographical situation. The sampling of the target population was consisted of selecting 20 individual maize growers per locality, for a total of 80 farmers. These farmers were identified in a database that was provided by the supervisory structure.

2.2.2. Characterization of farmers

The social characteristics of the farmers included gender, age, origin, education, experience in maize cultivation, land tenure status, affiliation to agricultural organizations or cooperatives and access to extension services and financing institutions. This information was collected from the individual farmers in the different locations and recorded in survey forms.

2.2.3. Characterization of cropping systems

The agronomic characteristics of the cultivation systems included, on the one hand, cropping operations such as tillage, ridging, weeding, application of fertilizers and pesticides, and the nature of the inputs used. On the other hand, these characteristics included acreage, crop association or rotation, nature of varieties, labor type, sowing method and planting period. The economic characteristics of the cultivation systems included the cost of cropping

operations (i.e. plowing, ridging, fertilization, pest control, harvesting), the cost of agricultural inputs (seeds, fertilizers, pesticides), the outputs (total production and revenues) and profitability. The profitability (economic return to production) was calculated for individual farmers following the formula described by [10]:

$$\text{Profitability} = (\text{Yield} \times \text{Price} \times 1000) - \text{Production cost}$$

Where Yield in t ha^{-1} , Price in Euro kg^{-1} and Profitability in Euros ha^{-1} .

This calculation was based on farm gate price for maize, and the production cost included labor cost for all field operations and input cost. The selling price of maize and the purchase cost of inputs varied according to the farmers.

2.2.4. Characterization of cultivation constraints

The production constraints were identified by the 20 individual farmers in each location and ranked on a 1 to 4 scale according to their significance. A score was assigned to each constraint according to the number of farmers concerned: 1 = less important (less than 5 farmers), 2 = moderately important (5-10 farmers), 3 = very important (10-15 farmers), and 4 = highly important (more than 15 farmers). These production constraints, together with farmers' social characteristics, technical routes and outputs (yields, income and profitability), were further used to assess the strengths and weaknesses of the cropping practices.

2.2.5. Statistical analysis

The 20 individual farmers in each location were first grouped into classes for the different characteristics. The number of classes varied according to the parameter under consideration. The social characteristics were grouped into two classes (A and B), and the agronomic and economic characteristics of the cropping systems into two or three classes (A, B and C). The data collected were subjected to an analysis of variance, using the SPSS (Statistical Package for Social Sciences 20.0) software. In the data processing, the locations were used as replicates to compare the means of the classes for the different parameters.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Social characteristics of farmers

The social characteristics of the maize growers are presented in (Table 1). Analysis of variance showed highly significant differences between classes for each social parameter ($P \leq .01$). The comparison of the means showed that the farmers were composed mainly of

native Senoufo (98%) and men (99%), with ages ranging from 20 to 40 years for 76.66% of the respondents. They were mostly illiterate (74.99%) and members of agricultural associations or cooperatives (91.7%). Most of them had poor access to financial institutions, and received training from technical support structures (99.5%).

3.1.2. Agronomic characteristics of field operations

The characteristics of field operations are presented in (Table 2). The analysis of variance showed highly significant differences between the classes for each parameter ($P \leq .01$). The comparison of means showed that 84.3% of the farmers cultivate maize on ploughed land, with or without ridging. They broadly apply fertilizers and pesticides, mainly mineral fertilizer for 98.5% and chemical pesticides for 98.00% of the respondents.

3.1.3. Agronomic characteristics of cropping systems

The agronomic characteristics of the maize-based cropping systems are presented in (Table 3). The analysis of variance showed highly significant differences between the classes for each parameter ($P \leq .01$). The comparison of means showed that 95% of the farmers did cultivate maize on land areas from 5 to more than 11 hectares and mainly in intercropping system representing 53.16% of the respondents. The plant material used is mostly composed of improved crop varieties in 79.16% of cases. The field operations are mostly carried out by family labor for 94.5% of farmers.

3.1.4. Economic characteristics of cropping systems

The economic characteristics of the maize cropping systems are presented in (Table 4). The analysis of variance showed highly significant differences between the cropping systems for the productions parameters ($p\text{-value} \leq .01$). The comparison of means showed a high value of yield for intercropping ($5.90 \pm 0.1 \text{ t ha}^{-1}$), compared to alley cropping and mono-cropping systems, which gave values of 4.33 ± 0.30 et $2.73 \pm 0.29 \text{ t ha}^{-1}$ respectively. Profitability was higher for the intercropping system ($744.26 \pm 50.54 \text{ Euros ha}^{-1}$) and lower for alley cropping and mono-cropping, which gave statistically similar values of 560.49 ± 71.98 and $413.48 \pm 140.89 \text{ Euros ha}^{-1}$ respectively.

3.1.5. Constraints of maize-based cropping systems

The significance scores of the prevalent maize production constraints are presented in (Table 5). The analysis of variance showed highly significant differences between the production constraints with respect to their importance in the perception of the farmers ($P = .00$). The comparison of means showed higher scores for low financial support and lack of agricultural inputs, with values of 4.00 ± 1.41 and 3.50 ± 0.71 , respective

Table 1. Social characteristics (in percent) of the maize growing farmers in the agro-ecological zone of Korhogo

Classes	Gender	Age	Origin	Land tenure	Education	Organization	Extension
A	99.0 (1.4) ^a	76.66 (9.42) ^a	98.00 (2.83) ^a	99.0 (1.4) ^a	74.99 (23.57) ^a	91.7 (11,8) ^a	99.5 (0.7) ^a
B	1.0 (1.4) ^b	23.33 (9.42) ^b	2.00 (2.83) ^b	1.0 (1.4) ^b	24.99 (23.57) ^b	8.3 (11,8) ^b	0.5 (0.7) ^b
Sample size	80	80	80	80	80	80	80
Means	50.0 (56.6)	50.0 (31.74)	50.0 (55.47)	50.0 (56.6)	49.9 (34.69)	50.0 (49,1)	50.0 (57.2)
<i>P-value</i>	.00	.00	.00	.00	.01	.02	.00
Signification	HS	HS	HS	HS	HS	HS	HS
Class							
identification :							
A	Men	20 – 40	Natives	Ownership	Illiterates	Member	Full access
B	Women	41 – 70	Non-natives	Rental	Literates	Non-member	Poor access

*Different letters per column indicate significant difference for classes (A, B) at $P < .05$ and values between brackets are standard deviations; HS: Highly significant.

Table 2. Agronomic characteristics (in percent) of the maize farming operations in the agro-ecological zone of Korhogo

Classes	Soil tillage	Soil fertilization	Pest control	Crop weeding	Fertilizer type	Pesticide type
A	84.3 (1,4) ^a	95.8 (5.8) ^a	91,7 (11.8) ^a	99,00 (1.41) ^a	98.50 (0,71) ^a	98.0 (2.8) ^a
B	15.7 (1,4) ^b	4.2 (5.8) ^b	8,3 (11.8) ^b	1,00 (1.41) ^b	1.50 (0,71) ^b	2.00 (2.8) ^b
Sample size	80	80	80	80	80	80
Means	50.0 (39.6)	50.0 (53.1)	50.0 (49.1)	50.00 (56.59)	50.00 (56.01)	50.0 (55.5)
<i>P-value</i>	.00	.00	.02	.00	.00	.00
Signification	HS	HS	HS	HS	HS	HS
Class identification:						
A	Appliers	Appliers	Appliers	Chemical	Mineral	Chemical
B	Non-appliers	Non-appliers	Non-appliers	Manuel	Organic	Organic

**Different letters per column indicate*

significant difference for classes (A, B, C) at $p < 0.05$ and values between brackets are standard deviations; HS: Highly significant

Table 3. Agronomic characteristics (in percent) of the maize cropping systems in the agro-ecological zone of Korhogo

Classes	Cropping systems	Crop varieties	Farm acreage	Operational workforce
A	33.33 (0.00) ^b	79.16 (5.89) ^a	4.15 (5.87) ^b	94.50 (4.95) ^a
B	53.16 (5.89) ^a	15.66 (11.79) ^b	54.17 (17.68) ^a	5.50 (4.95) ^b
C	20.83 (5.89) ^b	14.16 (5.89) ^b	41.66 (23.58) ^a	0.00 (0.00) ^c
Sample size	80	80	80	80
Means	36.11 (15.51)	33.33 (36.51)	33.32 ± 26.89	50.00 ± 51.54
<i>P-value</i>	.01	.01	.02	.00
Signification	HS	HS	HS	HS
Class identification:				
A	Mono-cropping	Improved	1- 4 ha	Familial labour
B	Intercropping	Traditional	5 -10 ha	Hired labour
C	Alley cropping	Both users	Over 11 ha	Both users

*Different letters per column indicate significant difference for classes (A, B, C) at $p < 0.05$ and values between brackets are standard deviations; HS: Highly significant.

Table 4. Economic characteristics of the maize cropping systems in the agro-ecological zone of Korhogo

Agro-systems	Production (t ha ⁻¹)	Revenue (FCFA ha ⁻¹)	Profitability (FCFA ha ⁻¹)	Profitability (Euros ha ⁻¹)
Intercropping	5.90 (0.1) ^a	772,200 (67,800) ^a	486,800 (33,300) ^a	741.9 (50.7) ^a
Alley cropping	4.33 (0.30) ^b	576,000 (39,000) ^b	366,400 (58,900) ^{ab}	558.4 (89.7) ^{ab}
Mono-cropping	2.73 (0.29) ^b	505,300 (80,500) ^b	270,200 (92,600) ^b	411.8 (141.1) ^b
Sample size	80	80	80	80
Means	4.22 (1.39)	617 800 (133,600)	374,50 (110,100)	570,7 (167.6)
<i>P-value</i>	.00	.01	.02	.02
Signification	HS	HS	S	S

*Different letters per column indicate significant difference at $p < .05$ and values between brackets are standard deviations; S: Significant; HS: Highly significant.

Table 5. Significance scores (on a 1 to 5 scale) for the maize cultivation constraints in the agro-ecological zone of Korhogo

Constraints	Scores
Poor soil fertility	1.50 (0.71) ^b
Poor funding	4.00 (1.41) ^a
Land pressure	2.00 (0.00) ^b
Low rainfall	1.00 (0.00) ^b
Limited inputs	3.50 (0.71) ^a
Poor organization	1.50 (0.71) ^b
Pest pressure	1.00 (0.00) ^b
Marketing problems	2.00 (0.00) ^b
Sample size	80
Means	2.06 ± 0.48
<i>P-value</i>	.00
Signification	HS

*Different letters per column indicate significant difference at $p < .05$ and values between brackets are standard deviations; HS: Highly significant.

3.2. DISCUSSION

The results of the social characterization showed that the majority of maize producers were native Senoufo, predominantly young (age ranging from 20 to 40 years) and men, with no formal education. Most of them were member of farmers' organizations and had full access to extension services, but with a poor financial support. The predominance of men farmers could be explained by the Senoufo tradition, whereby land is exclusively inherited by men and is transferred to nephews, according to the so-called matrilineal succession. This rigidity of traditional land allocation and devolution regulations is an obstruction to the intensification of agricultural production. The national and indigenous status of farmers provides an opportunity to access land ownership or renting and financial supports. The availability and land tenure status, the age of the farmers (between 20 and 40 years), their affiliation to organizations and the natural vegetation patterns (shrubby and herbaceous savannah), are drivers of the expansion of the cultivated land area. The results showed that most of the farmers were illiterates and had poor access to financial supports. The poor education of farmers could be a barrier to the implementation of agricultural technologies and to the drafting of a business account often required to obtain funding. This social constraint needs stronger involvement of supervisory structures and extension services in capacity building and in improving farmers' knowledge on sustainable practices [11].

The results of agronomic characteristics showed that the bulk of the farmers use improved maize varieties, apply mineral fertilizer at various rates for soil nutrient replenishment and chemical pesticides for pest control. The mineral fertilizer formulation (NPK 23-10-5 + 3 S + 2 (MgO) + 0.3 Zn) and application rates of 200 to 250 kg ha⁻¹ that is advocated to farmers for maize cultivation is not widely implemented due to problems of availability and affordability. Rather than implementing better fertilizer and pesticide formulations, some farmers are using available nutrient resources (appropriate or not) and other crop protection products that are recommended for non-food or cash crops production such as cashew and cotton. This practice is not typical of maize cultivation, but is also applied to many other food crops (i.e. rice, fonio, millet and sorghum). The rate of fertilizer application ranged between 50 and 150 kg ha⁻¹ for most farmers, which is below the recommendation of the farmer organizations. Blanket recommendation of fertilizer application, without taking into account crop requirements and soil nutrient availability, is underpinned by limited access to conventional soil analyzing methods, and stressing the need for farmer-scale soil fertility monitoring tools. This suggestion is an incentive to the world scientific community for the development and release of simplified and reliable analytical tools for soil mineral diagnosis, given the knowledge-intensive nature of conventional methods.

The unreasonable use of fertilizers and crop protection products is a factor contributing to the degradation of natural resources (pollution of agro-ecosystems, reduction of biodiversity) and represents a health threat for farmers and consumers [12]. The maize-based cropping systems are diversified, with the predominance of intercropping. The prevalence of intercropping system is a response to farmers' need to diversifying incomes and livelihoods and to increase their resilience to adverse environmental conditions. In the mixed cropping systems, the most common intercrop for maize was rice, which is a nutrient-demanding and depleting crop that competes with maize for soil resources. They are characterized by a low profitability, ranging from $744,26 \pm 50,54$ Euros ha^{-1} for the mono-cropping to $413,48 \pm 140,89$ Euros ha^{-1} for the alley cropping. The low productivity (yields and economic return to production) of the maize cultivation systems could be explained by the unsuitability of technology (use of inadequate fertilizer and pesticide formulations, inappropriateness of application rates and periods) and by the erratic or changing rainfall patterns and lack of efficient water management technology. Profitability can further be hampered by the fluctuating price of maize on local markets and post-harvest losses due to the lack of appropriate storage methods [13; 14].

Weaknesses of traditional maize cultivation systems include poor access and unsuitable use of agricultural inputs, poor financial support, lack of knowledge on sustainable practices, fluctuating maize prices and lack of a reliable marketing chains. Thus, the attempt to intensify smallholder current farming systems could be geared towards sound agronomic principles, including the implementation of the Integrated Pest and Disease Management, minimal tillage and mulching of soils to reduce susceptibility to erosion. This could moreover involve the application of organic manure (compost, bio-char), rotation or association of legumes and integration of insect pest repellent plants. Furthermore, sustainability efforts need to be focused on the utilization of maize varieties with higher nutrient use efficiency and with flour-to-grain extraction rate, and on strengthening farmers' knowledge or capacities on sustainable agricultural practices and development of reliable marketing chains. This study was focused on maize cultivation and needs be extended to all food crops, in order to sustainably increase agricultural production and to enhance the socioeconomic conditions of farmers.

4. CONCLUSION

The survey provides insights on the unsustainability of the smallholder maize farming practices in northern Côte d'Ivoire. Results showed that most of the farmers were native and men, without formal education that impairs the implementation of agricultural innovations.

The cultivation was predominantly intercropping systems and characterized by low yields and economic returns. The weaknesses of the cultivation systems include poor using and access to agricultural inputs and to financial supports, unsuitable technologies, low prices of outputs and lack of reliable marketing chains. The affiliation of farmers to organizations and their native status warrant the opportunity to access land ownership and rental and to financial supports. Sustainability attempts of the farming systems can be geared towards the implementation of the Integrated Pest and Disease Management approach, alongside with minimal tillage, soil mulching, application of manure and moderate rates of mineral fertilizer and integration of insect pest repellent plants, combined with strengthening farmers' knowledge on sustainable practices and reliable marketing chains.

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