

The Use of Chemical Fertilizers by Maize (*Zea mays* L.) Producers and Soil Fertility Parameters Importance in West Mayo-Kebbi Province, Chad

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Abstract

Soil fertility management and the use of mineral fertilizers are crucial issues for agriculture in sub-Saharan Africa. In regions such as the Sudanian zone of Chad, where soils are sandy and nutrient-deficient, according to producers, the adoption of chemical fertilizers is common, but remains poorly documented from both socioeconomic and scientific perspectives in the city of Pala. In a context of increasing demographic pressure, climate variability, and land degradation, agricultural systems in the Sudanian zones face major challenges. This study examines chemical fertilizer use practices among 200 maize producers and physicochemical analyses of composite soil samples from three sites of Pala (Dapambaye, Herdé, and Goïgamla). The majority of producers report that they use NPK 20-10-10 chemical fertilizer (68%) and urea (28%) to support maize production, but this is limited by high cost, which is the main constraint. These soils are predominantly sandy-loam with low water-holding capacity and low nutrient content. Maize production mainly involves men (81%) and young people. The results reveal considerable variability in soil fertility which are poor, with few acidity (pH values 6.06 - 6.53), generally low nitrogen content at Dapambaye (0.026%) and higher contents at Herdé (0.208%) and Goïgamla (0.182%); total phosphorus is low and less variable (60 - 66 ppm), the levels of organic matter (1.61, 2.75, and 3.28%) and mineral elements are variable. This study suggests the need to promote agro-ecological

alternatives by increasing the water and nutrients holding capacity by organic matter, symbiosis by beneficial microorganisms (biological nitrogen fixation by legume-rhizobia and phosphorus availability with mycorrhizal fungi).

Keywords

Chemical Fertilizers, Soil Fertility, Socioeconomic Study, Agroecological Management, Pala, Chad

1. Introduction

A socioeconomic study is an analytical approach that aims to examine the social and economic dimensions of a system in tandem in order to understand the behaviors of actors and the factors influencing their decisions [1] [2]. In particular, it makes it possible to assess the interactions between agricultural practices, producers' living conditions, and the use of natural resources. On a global scale, rapid population growth poses a major challenge to food security. According to the United Nations, the world's population has exceeded 8 billion and is projected to reach nearly 9.7 billion by 2050, which will lead to a significant increase in food demand [3]. For the FAO, agricultural production will need to increase by approximately 70% to meet future food needs [4]. In sub-Saharan Africa, nutritional deficits vary widely, but strong demographic pressure calls for a new approach involving better fertilizer management to improve soil health and ensure sustainable agricultural production [5]. Chad is an example of one of the world's least productive countries where agriculture is an essential pillar of the economy, despite vulnerable production systems. Agriculture in Chad employs more than 70% of the working population and contributes significantly to the gross domestic product [6]. However, this sector faces numerous constraints, including climate variability, declining soil fertility, erratic rainfall, and land-use conflicts [7]. Agricultural production in Chad remains heavily dependent on climatic variability and the inherent, often limited, capacity of the soils. Previous studies conducted in Chad and other regions of Africa have shown that agricultural soils are generally deficient in essential nutrients, particularly nitrogen (N), phosphorus (P) and organic matter [8]-[10]. Furthermore, soils in the Sudanese zones are often characterized by sandy to sandy-loamy textures, which limit their capacity to retain water and nutrients [6]. This situation is associated with constraints on agricultural production, particularly for maize cultivation, the region's primary food crop [11]. In response to declining soil fertility, the use of chemical fertilizers has become widespread in an effort to improve yields. These chemical inputs provide a rapid supply of soluble major nutrients such as nitrogen, phosphorus, and potassium (K) [12]. However, access to these fertilizers remains limited for many farmers due to their high cost, particularly in developing countries [13]. Furthermore, inadequate market access to inputs in rural areas poses an additional barrier to their adoption [14]. Recent studies

have shown that the exclusive use of chemical fertilizers, without the addition of organic matter, can lead to progressive soil degradation, including a decrease in organic carbon, acidification, pollution and disruption of biological activities [10] [15]. This situation underscores the need to adopt integrated soil fertility management approaches that incorporate sources of organic matter, judicious application of mineral nutrients, and beneficial organisms activities. According to data from the Foreign Agricultural Service [16] available in Crop Explorer, for the 2024/2025 crop year, the area planted with corn in Chad was estimated at 330,000 ha, with a production of 394,000 metric tons and an average yield of 1.19 metric tons per ha. For the 2025/2026 crop year, the harvested area remained estimated at 330,000 ha, while production was estimated at 380,000 metric tons, with an average yield of 1.15 metric tons per ha indicating a slight decrease in the corn yield. Consequently, integrated soil fertility management (ISFM) appears to be a relevant strategy, combining an adequate use of mineral fertilizers, organic amendments, and beneficial microorganisms [8] [17]. Among these beneficial microorganisms, arbuscular mycorrhizal fungi (AMF) play a major role in improving the uptake of water and nutrients (particularly phosphorus) and in enhancing crop resilience to biotic and abiotic stresses [18]. Despite the importance of these issues, few studies have taken an integrated approach to the socioeconomic aspects related to the use of chemical fertilizers and the physicochemical characteristics of soils in Chad, particularly in the city of Pala. This gap limits the overall understanding of the interactions between agricultural practices, economic constraints, and soil fertility. The objectives of this study are: (i) to characterize the socioeconomic aspects of maize production systems by farmers in the city of Pala; (ii) to obtain data on the use of chemical fertilizers and the barriers to their adoption; and (iii) to assess the physicochemical characteristics of soils at three representative sites of Pala. For maize production optimization, it is essential to understand nutrient requirements based on soil characteristics [14] [19]. For example, for sandy-loam soils, the application of complete NPK fertilizers (250 kg/ha) which can be broken down into 100 - 150 kg N/ha (in 2 or 3 applications), 40 - 60 kg P₂O₅, and 50 - 100 kg K₂O is essential [20]. Soil nutrient management is particularly important in the context of Chad, where improving agricultural productivity is a major challenge for food security and poverty reduction.

2. Methodology

2.1. Equipment

2.1.1. Study Site

The study was conducted in the West Mayo-Kebbi region, in the town of Pala, in southwestern Chad. Three sampling sites were selected: **Dapambaye** (9°33'44.26"N; 14°50'42.73"E), **Herdé** (9°22'15.74"N; 14°50'15.88"E) and **Goïgamla** (9°19'12.34"N; 14°52'29.26"E). These sites were selected based on their history of agricultural use involving chemical inputs, in order to cover the province's soil and agroecological diversity.

The climate is the Sudanian type, characterized by two seasons: a long dry season from November to May and a rainy season from May to October. Precipitation ranges from 800 to 1,200 mm per year. Temperatures range from 14°C (minimum) to 45°C (maximum). The soils are generally sandy-clay-loamy in texture [21]. Physicochemical analyses were conducted at the Soil Microbiology Laboratory of the Biotechnology Centre at the University of Yaoundé I, in Yaoundé-Nkolbisson, Cameroon (Figure 1).

2.1.2. Map of Experimental Sites

City of Pala West Mayo-Kebbi Province, Republic of Chad.

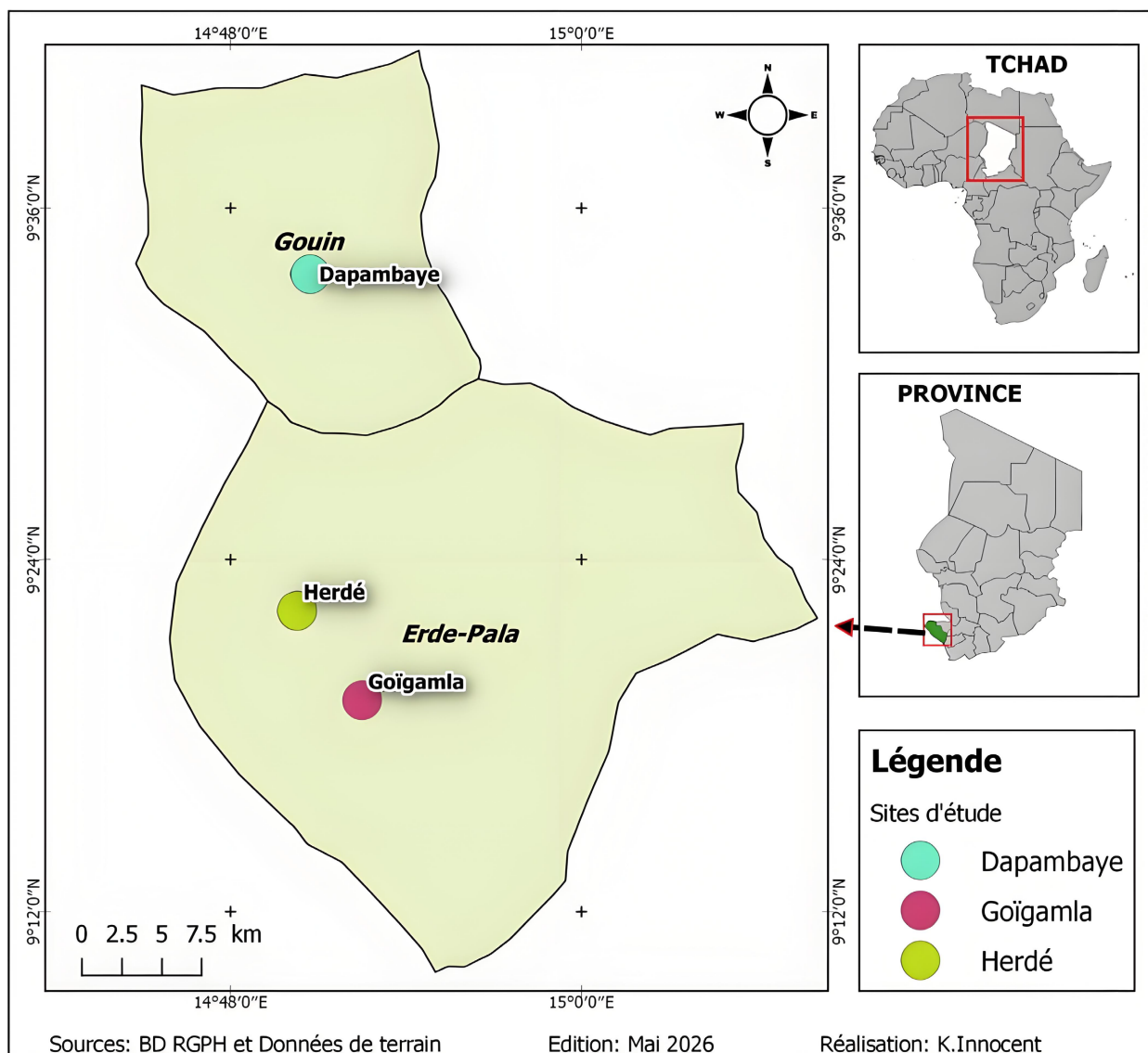


Figure 1. Location of the three sampling sites in the city of Pala, West Mayo-Kebbi Province, Chad (2025).

2.2. Technical Equipment

Fieldwork required the following equipment: a shovel for preparing sampling

points, a Sony camera for taking pictures, a GPS device for geolocating sites, an auger for soil sampling, labeled plastic bags for sample storage, questionnaire forms, and writing. For laboratory analyses, standard soil analysis equipment was used, including a pH meter, an atomic absorption spectrophotometer, and 2-mm mesh sieves.

2.2.1. Socioeconomic Survey Methodology

The socioeconomic survey was conducted in the city of Pala during the month of April 2025, at the start of the agricultural season. It aimed to document agronomic and socioeconomic aspects, farming practices, and constraints related to the availability of agricultural inputs. Preliminary interviews were conducted with leaders of local farmers' organizations (notably the National Agency for Rural Development, ANADER) prior to the individual administration of the questionnaires.

The surveys were conducted among an initial sample of 210 farmers selected randomly in the town of Pala. Of these, 200 farmers actually completed the questionnaire and were included in the analysis, representing a response rate of 95 percent. Eligible farmers were active maize growers in the study area. The 10 non-respondents were not included in the analysis, and no replacements were made. The paper questionnaires covered: the farmer's sociodemographic profile (gender, age, education level), farm size and type, types of fertilizers used, sources of supply, frequency and costs of use, as well as barriers to adopting alternative practices. The collected data were analyzed using IBM SPSS 20.0 software. The three sites Dapambaye, Herdé, and Goïgamla correspond to the soil sampling sites; they do not constitute separate survey strata.

2.2.2. Determination of the Physicochemical Characteristics of Soils at the Study Sites

1) Collection and Preparation of Soil Samples

Soil samples were collected during the dry season using the zigzag method described by [22], at a depth of 0 - 20 cm [23]. At each site, 25 kg of soil were collected from 10 different maize plants. The samples were then sieved using a 2-mm mesh sieve to remove coarse particles, then homogenized to form a separate composite sample weighing at least 20 kg per site. A 1-kg subsample per site was packaged in labeled plastic bags and stored at room temperature until analysis in the laboratory. Each composite sample (Dapambaye, Herdé, and Goïgamla) was analyzed in triplicate. These analytical replicates correspond to data from the same composite sample and not to independent field replicates.

2) Physicochemical Analysis of Soils

The physical and chemical properties of the soils were determined using the following standardized methods: soil pH was measured from a soil-water suspension (1:2.5, w:w) according to Pansu & Gautheyrou [24], organic carbon was determined using the hot oxidation method described in [25]. The organic matter content is obtained by applying a multiplication factor of 1.724, total nitrogen: was determined using the Kjeldahl method [26] following mineralization and titration, cation exchange capacity (CEC) was measured according to the method

in [27], exchangeable bases (Ca^{2+} , Mg^{2+} , K^{+}) were extracted using ammonium acetate (NH_4OAc , pH 7) and quantified by flame atomic absorption spectrophotometry, available phosphorus was extracted and determined according to the Olsen method [28], total phosphorus was determined according to Pansu & Gaucheyrou [24], particle size distribution was determined according to French classification standards [29], allowing for the distinction of sand, silt, and clay fractions.

3) Statistical Analyses

Data analysis was performed using IBM/SPSS 20.0 software. A one-way analysis of variance (ANOVA) was conducted, followed by a Tukey post hoc test at a 5% significance level, to compare the means across the different sites. The results are presented as mean $\pm$ standard deviation. Graphs were created using Excel 2016. The interpretation of the ANOVA and Tukey's test results is limited to the following analytical framework: analytical replicates correspond to data from the same composite sample and not to independent field replicates.

3. Results

3.1. Socioeconomic Profile of Farmers

3.1.1. Profile by Gender

The survey results show a clear predominance of men among corn producers: men account for 81% of respondents, compared to 19% for women, as shown in **Figure 2**. This distribution reflects traditional agricultural dynamics in the region, where women tend to focus more on vegetable farming. The most represented age group is 30 to 40 years old (72%), followed by 20 to 29 years old (28%).

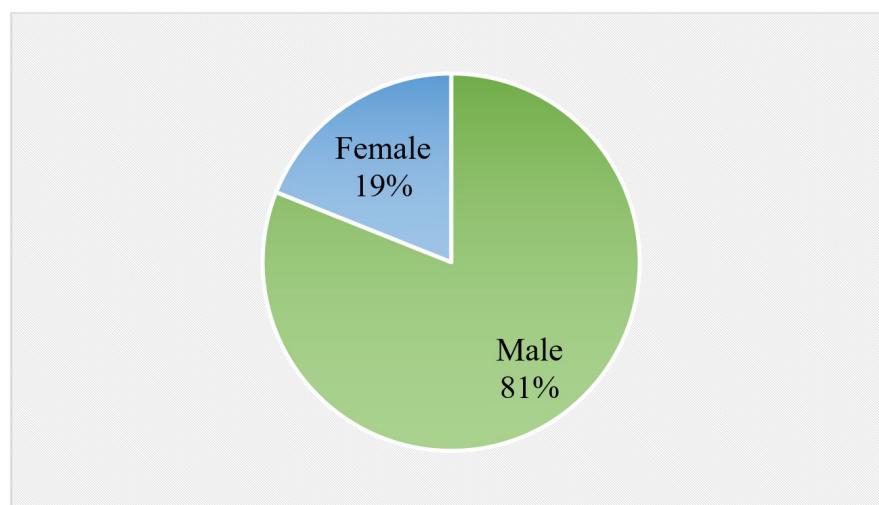


Figure 2. Socioeconomic profile of corn producers in Pala city West Mayo-Kebbi Province, Chad by gender.

3.1.2. Social Profile by Education Level and Farm Size

The majority of producers (62%) have received only a primary school education or no formal education at all. This situation may hinder access to technical infor-

mation and the adoption of innovative agricultural practices. In terms of land area, 55% of farms are smaller than 1 ha, 38% range from 1 to 5 ha, and only 7% exceed 5 ha. The overall socioeconomic profile is summarized in **Table 1**.

Table 1. Socioeconomic profile of maize farmers surveyed in the city of Pala, West Mayo-Kebbi Province, Chad.

Variables	Categories	Number	Frequency (%)
Gender	Male	81	81
	Female	19	19
Age group	20 - 29 years	28	28
	30 - 40 years old	72	72
Farm size	<1 ha	55	55
	1 - 5 ha	38	38
	>5 ha	7	7
Level of education	Elementary school/no formal education	62	62
	High school and above	38	38

3.2. Agricultural Practices and Use of Chemical Fertilizers

3.2.1. Types of Chemical Fertilizers Used

NPK 20-10-10 is the most commonly used type of fertilizer in the survey data (68%), followed by urea (22%), while some producers also combine NPK 20-10-10 and urea (10%). The fertilization practice reported in the area amounts to four 50 kg (presumably) bags (200 kg) of fertilizer per ha; that is, two bags of 50 kg NPK 20-10-10 and two bags of 50 kg urea applied in two applications (the 1st during the 1st weeding and the 2nd during flowering). Since the 50 kg unit weight of the bags has not been documented in the currently available data, the application rates are expressed in number of presumed bags of 50kg per ha.

3.2.2. Sources of Fertilizer Supply

Local markets and private dealers are the primary source of fertilizer for 76% of producers. Government programs (subsidies and grant programs) account for 18% of supplies, while NGOs and agricultural projects contribute 6%.

3.2.3. Methods of Applying Chemical Fertilizers

The reported application practice involves two applications during the growing season: the first during the second weeding and the second during flowering. This regime amounts to presume 200 kg of fertilizer per ha per growing season, divided among four presumed 25-kg bags of NPK 20-10-10 and four 25-kg bags of urea. In the absence of individual questionnaire responses, this method is presented as a reported practice rather than as a statistical frequency calculated across all producers.

3.2.4. Costs and Barriers to the Use of Chemical Fertilizers

The high cost of fertilizers is identified as the main obstacle by 74% of farmers.

The main findings regarding fertilizer application practices are summarized in **Table 2**. Lack of access to input markets (18%) and insufficient technical information (8%) are the other major constraints.

Table 2. Agricultural practices and use of chemical fertilizers in the city of Pala, West Mayo-Kebbi Province, Chad.

Aspect	Main practice	Frequency (%)
Type of fertilizer	NPK 20-10-10	68
	Urea	22
	NPK + Urea blend	10
Source of supply	Local market/retailers	76
	Government agencies	18
	NGOs/agricultural projects	6
Application frequency	2 applications: second weeding and flowering Reported practice	
Main obstacle	High cost of fertilizers	74
	Lack of market access	18
	Lack of technical information	8

3.3. Soil Fertility Management

3.3.1. Soil Texture

The soils at the three sites are predominantly sandy in texture. The proportions of sand, silt, and clay, as well as the textural classification, are presented in **Table 3**. The Herdé site is characterized by a very high sand content (95%), while Dapambaye (82%) and Goïgamla (80%) have sandy-silty profiles.

Table 3. Soil texture and type at the three sampling sites, city of Pala, West Mayo-Kebbi Province, Chad.

Sites	Texture (%)			Soil type
	Sand	Silt	Clay	
Dapambaye	81.00	15.59	2.60	Sandy-silt
Herdé	94.99	2.61	2.50	Sandy
Goïgamla	79.97	17.53	2.50	Sandy-silt

3.3.2. Physicochemical Analysis of Soils

The results of the physicochemical analyses show differences among the three composite soil samples studied (**Table 4**). pH values range from 6.06 (Dapambaye) to 6.53 (Goïgamla), indicating slightly acidic soils. Total nitrogen content is very low at Dapambaye (0.026%) and 7 times higher at Goïgamla (0.182%) and 8 times higher at Herdé (0.208%). Organic matter content is highest at Goïgamla (3.28%) compared to Herdé (2.75%) and Dapambaye (1.61%), suggesting better biological soil quality at Goïgamla. The observed total phosphorus contents are low and vary little (60 - 66 ppm), whereas potassium shows very high variability

between Herdé (38 ppm), Dapambaye (534 ppm), and Goïgamla (1472 ppm) 3.81 times higher than in Herdé and Dapambaye.

Table 4. Physicochemical parameters of soils at the three maize production sites in Pala, West Mayo-Kebbi Province, Chad.

Analyzed		Soil sampling sites		
Parameters	Dapambaye	Herdé	Goïgamla	
pH	6.06 ± 0.01	6.15 ± 0.01	6.53 ± 0.01	
Total N (%)	0.026 ± 0.01	0.208 ± 0.02	0.182 ± 0.02	
Total P (ppm)	65.8 ± 0.6	60.2 ± 0.6	62.3 ± 0.6	
K (ppm)	534 ± 2	38 ± 1	1,472 ± 3	
Ca (ppm)	60 ± 2	38 ± 4	100 ± 4	
Mg (ppm)	35.0 ± 0.1	20.5 ± 0.1	37.5 ± 0.1	
Na (ppm)	25.6 ± 0.1	25.6 ± 0.1	19.5 ± 0.1	
CEC (meq/100 g)	13.36 ± 0.20	10.98 ± 0.20	10.3 ± 0.10	
Carbon (%)	0.94 ± 0.10	1.60 ± 0.20	1.91 ± 0.20	
Organic matter (%)	1.61 ± 0.02	2.75 ± 0.03	3.28 ± 0.03	
Conductivity (mV)	8.41 ± 0.10	4.17 ± 0.29	12.00 ± 0.20	

Note: Values are expressed as the mean ± standard deviation of the three analytical replicates for each composite sample. These replicates do not constitute independent values. Values are expressed as the mean ± standard deviation of the three analytical replicates. The differences observed between sites are presented for descriptive purposes only and should not be interpreted as statistically significant differences between soil populations.

4. Discussion

The results of this study highlight the high level of involvement of men (81%) in maize cultivation in the city of Pala, while women (19%) tend to focus more on vegetable farming. This distribution is consistent with observations made in sub-Saharan Africa, where climatic vulnerability, limited access to productive resources such as land, irrigation, nutrients inputs, and credit remains structurally unequal by gender, thereby influencing agricultural production systems. Targeted policies to include women in the cereal production chain could significantly improve overall productivity [1]. The predominance of the 30 - 40 age group (72%) indicates a relatively young and active agricultural population. This finding is an asset for the adoption of agricultural innovations, as demonstrated by several studies that highlight how being of working age promotes the adoption of new agricultural practices, provided there is adequate access to information and training [30]. Nevertheless, the low educational level of the majority of producers (62% with only a primary education or no education at all) constitutes a persistent barrier to the adoption of innovative techniques. The results of the socioeconomic survey show that the cost of fertilizers (74% of cases) and supply difficulties are the main obstacles to rational fertilization. Dependence on local markets, where prices are often unsubsidized, partly explains the difficulties smallholders face in accessing these resources since NPK fertilizers cost is 22,500 to 25,000 CFA F and

urea 15,000 to 20,000 CFA F per 50 kg bag in Chad. Targeted public policies such as input subsidies, the development of supply cooperatives, and agricultural extension services are essential to improve small producers' access to fertilizers and sustainable alternatives in the city of Pala [14]. Since this study did not measure yields, it does not allow for establishing a direct link between fertilizer application methods and yield levels. From a pedological perspective, the soils studied are predominantly sandy to sandy-loamy in texture, which confirms observations regarding soils in the Sudanese zones of Chad [6]. The soils of West Mayo-Kebbi exhibit textural variability that results in low water-holding capacity, low nutrient availability, and thus low natural fertility, as well as generally low crop yields [9]. The low nitrogen content observed, particularly in Dapambaye (0.026%), indicates a level that is insufficient for high crop production. The total phosphorus contents measured in the studied soils are very low (60 - 66 ppm). This low total phosphorus content, combined with the soils' physicochemical characteristics, may contribute to limiting phosphorus availability to crops. However, low phosphorus availability is one of the major constraints on agricultural production in the Sudano-Sahelian zones [17]. The cross-sectional data from this study therefore do not allow these differences to be attributed to any specific agricultural practice. The slightly acidic pH values (6.06 to 6.53) are generally favorable for the availability of the major nutrients required by maize. The higher organic matter contents in Goïgamla (3.28%) indicate its key role in soil fertility by improving soil structure, water retention, and nutrient availability. Maintaining soil organic matter should therefore be a priority in fertility management strategies for example by improved fallow. The high variability in potassium between Herdé (38 ppm) and Goïgamla (1472 ppm) is particularly notable and warrants further investigation. However, the variations observed in potassium, calcium, and magnesium content reflects heterogeneity in soil chemical fertility, which requires a site-specific fertilization approach. The cation exchange capacity (CEC), ranging from 10.30 to 13.36 meq/100 g, indicates that sandy-loam soils have an average ability to retain nutrients supplied by mineral fertilizers. The leaching phenomenon generally observed in sandy soils partly explains farmers' heavy reliance on chemical fertilizers and the low efficiency of fertilizer applications when they are not split into multiple applications. Furthermore, a comparison between chemical fertilizer-based fertilization systems and the application of organic matter indicates better soil health, higher levels of nutrients (C, N, P), greater microbial activity, and higher yields [31]. However, since this study is cross-sectional and based on a composite sample per site, it does not allow for the establishment of a causal relationship between the use of mineral fertilizers and soil degradation. The judicious combination of minimal inorganic, selected organic matter inputs, and beneficial microbial sources may nevertheless constitute an alternative for the biological management of sandy soil fertility [5] [8]. The results show that the use of chemical fertilizers plays a significant role in the fertilization practices of the surveyed maize farmers, but need improvement by agro-ecological alternatives. Central Africa potential yield for maize is 5 - 6 t/ha under optimal management such

as rainfed and irrigation; comparing Central Africa and Chad maize yield on-farm is 1.5 - 2.6t/ha. [32]. Some experimental studies conducted in the same area lead to consistent observations from results obtained in smallholder settings in the Pala area by Goalbaye *et al.* [33] who reported high yields of 3.10 t/ha (2009TZEE-W-STR maize and 2009TZE-DT-STR maize varieties), compared with low yields of 1.48 t/ha (CMS8704 maize variety) and 2.04 t/ha (local maize variety control). When comparing Salamat (better rainfall: 3.1 t/ha) with Mayo Kebbi Ouest (lower inputs: 2.3 t/ha) regions, there is a potential of improvement [34]. Compound cereal fertilizer (N, P, K; 15-15-15) is applied as a base fertilizer at a rate equivalent to 150 kg/ha. Topdressing fertilizer, urea, is applied in two splits at the maize 10-leaf stage and at flowering, at equivalent amounts of 50 kg/ha and 30 kg/ha, respectively. No phytosanitary treatments are applied. These differences show that corn performance can be influenced by both genetic material and environmental factors such as nutrients availability and farmers cultural practices. In this context, the adoption of Integrated Soil Fertility Management (ISFM) strategies appears essential. [17] recently demonstrated that the combination of reduced mineral fertilizers and specific organic amendments can sustainably improve soil fertility and maize yields under African conditions. According to Agricultural land potential of soils from Chad is low and average nutrient depletion in Chad is more than 30 - 60 kg NPK/ha with only 180 - 269 length in growing period. African soils (except forest zones) are inherently poor in soil organic carbon, and sandy soils are low in clay content, very low in cation exchange capacity, and annual losses are high, can reach 4.7% [35]. These authors recommend the use of inorganic fertilizers and recycling organic amendments improving nutrient use efficiency and integrated fodder to livestock, but micro dosing is also considered as pathway to Africa's green revolution [36] [37]. Managing tropical sandy soils requires boosting organic matter and soil organisms to overcome poor nutrient and water retention. Examples of increasing organic matter such as green manures and crop residues; stimulating biological activities (beneficial micro-organisms, soil fauna), plant cover crops, use biochar and crop-livestock integration. The combined use of integrated management of organic matter, inorganic fertilizers, biofertilizers such as arbuscular mycorrhizal fungi (AMF), have proved a promising approach for sustained crop production, by improving nutrient uptake, crop resilience to water and nutritional stress under climatic constraints [8] [18] [38] [39].

5. Conclusion

This study described the socioeconomic characteristics of maize farmers and the physicochemical parameters of soil fertility in the city of Pala, West Mayo-Kebbi Province, Chad. The results show significant male involvement in maize production and a predominantly young farming population, representing significant potential for the adoption of new agricultural technologies. In terms of soil characteristics, the soils studied are predominantly sandy to sandy-loamy, with a slightly acidic pH and low water and nutrient retention capacity. They have low nitrogen and phosphorus contents and highly variable potassium levels. Organic matter

content is moderate in Dapambaye, high in Herdé, and very high in Goïgamla. Farmers report using chemical fertilizers primarily NPK 20-10-10 and urea to support maize production, but their use remains limited by high costs and availability. Since no yields were measured and no long-term monitoring of soil fertility was conducted, this study cannot demonstrate an effect of fertilizers on yield nor establish that the exclusive use of mineral fertilizers has caused progressive soil degradation. In light of these observations, we believe it is necessary to adopt more sustainable agricultural practices based on Integrated Soil Fertility Management (ISFM). The judicious use of mineral fertilizers, such as micro dosing and biochar application, organic amendments, and biostimulants such as arbuscular mycorrhizal fungi (AMF) represents a promising alternative for improving maize productivity while preserving soil quality in the Sudano-Sahelian regions of Chad. AMF possess numerous beneficial properties for mitigating the major constraints observed in these sandy soils: stimulation of beneficial functions such as the uptake of water and poorly mobile nutrients, and improved tolerance to biotic and abiotic stresses. Supporting policies (subsidies, training, extension services) are essential to make these agroecological practices accessible to smallholder farmers.

Author Contributions

Conceptualization, Izaba Aimée and Nwaga Dieudonné; methodology, Izaba Aimée; software, Mbassi Manga Gilbert; validation, Nwaga Dieudonné, Nguinambaye Mberdoun Memti, and Fokom Raymond; formal analysis, Nwaga Dieudonné; investigation, Izaba Aimée; resources, Izaba Aimée; data curation, Izaba Aimée and Mbassi Manga Gilbert; writing original draft preparation, Izaba Aimée; writing review and editing, Izaba Aimée and Nwaga Dieudonné; visualization, Nkameni Djeuga Thierry; supervision, Nguinambaye Mberdoun Memti; project administration, Izaba Aimée and Nwaga Dieudonné; funding acquisition, Izaba Aimée; translation into English, Nkameni Djeuga Thierry. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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