

# Soil Survey and Evaluation of Agricultural Potential: Case Study of the “SANAD” Perimeter in Abagarde, Chari Baguirmi Province, Chad

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## Abstract

This study assesses the agricultural potential of soils within the “SANAD” project perimeter in Chad. Using field surveys, laboratory analysis, and a land evaluation framework, the authors identify four soil mapping units. The results indicate that the soils have medium fertility and are suitable for a range of irrigated and rainfed crops, with specific recommendations provided for different soil units. The results show that, along a toposequential cross-section (east-west direction), four mapping units can be identified. Mapping units 1 and 2 are suitable for irrigated maize, rice, and sorghum crops, as well as market garden crops (tomatoes, cabbage, and green beans), while mapping units 3 and 4 are suitable for upland rainfed rice, other cereals (maize, sorghum, millet), and legumes. Overall, the soils within the “SANAD” perimeter are classified as having medium fertility.

## Keywords

Sequential Topography, Soils, Suitability, Irrigated Crops, Rainfed Crops

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## 1. Introduction

Chad, like other Sahelian countries, experiences food insecurity due to low agricultural productivity. This is due, on the one hand, to climate variability and, above all, to soil depletion, the causes of which are both natural and human-induced. Chadian agriculture remains largely rain-fed and shifting, dependent on climatic

conditions. Farming techniques remain traditional and inefficient, particularly slash-and-burn agriculture alternating with fallow periods. [1] observed environmental crises forcing the population to choose between emigration and modification of the production system inherited from their ancestors. This results in a succession of periods of crisis and more stable periods, during which production systems adapted to each land situation emerge. Irrigation in the context of climate change presents major challenges, including increased water demand and changing climatic conditions that can affect water availability. The history of irrigation is long in Sub-Saharan Africa. During the colonial period, France supported the development of irrigable areas in Francophone Africa [2]. The development of irrigation, implemented by the major colonial companies, aimed at exporting high-value tropical products to the metropolis as well as meeting the basic food needs (rice) of the colonies [3]. In a context of increasing pressure on water resources, it is estimated that feeding 9 billion people by 2050 will require a 70% increase in global agricultural production [4]. Water is a key factor in this challenge. Globally, irrigation accounts for 70% of water withdrawals, while representing only 40% of global agricultural production and 20% of cultivated land [5]. Furthermore, climate change is creating significant uncertainty about future water availability [6]. Therefore, a frequently stated objective is to produce more crop per drop of water used for agriculture—that is, to improve water productivity. Using more efficient irrigation systems, crop diversification, and sustainable water management are essential to ensuring climate-resilient agriculture. It is in this perspective that this study, which as a prelude to a conceptual and dimensioning study of the “SANAD” perimeter in Mandelia in the province of Chari-Baguirmi, has set itself the objective of surveying the soils of the perimeter and their adaptability to the types of crops envisaged.

## 2. Materials and Methods

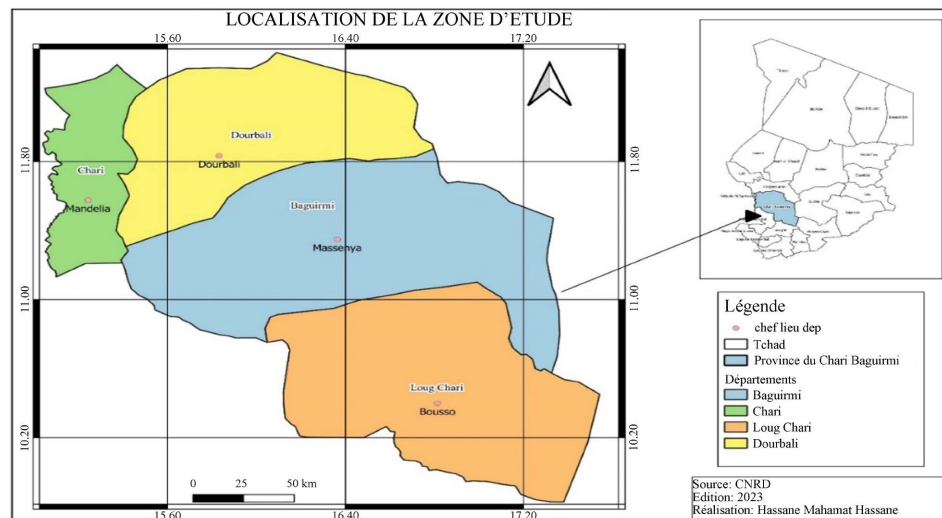
### 2.1. Materials

#### Localization

The Food Security, Nutrition and Sustainable Agriculture (SANAD) perimeter to be developed, the subject of this study, is located near the village of Abagarde, approximately 43 km south of N'Djamena. Administratively, the future hydro-agricultural development “SANAD” is located in the Chari Department, Chari-Baguirmi Province (**Figure 1**).

### 2.2. Methods

The method adopted for conducting this study consisted of gathering three pieces of information, all of which could contribute to better i) identifying the soil formations within the perimeter, ii) determining their fertility levels, and iii) finally, assessing their suitability for the agricultural activities planned within the perimeter. The methods used to acquire each of these three pieces of information are described in the paragraphs below.



**Figure 1.** Map showing the location of the study area.

### 2.2.1. Soil Survey

The soil survey was carried out by four teams and covered an actual area of 365 ha. A total of 365 observations were made, including 365 soil pits, at a rate of one observation per ha. The survey method used was systematic gridding combined with toposequence analysis. Soil profiles were described according to [7]. Horizon colors were determined using the Munsell Code. Various details about the profile and its environment (depth, color, structure, texture, gravel content, biological activity, vegetation, and/or cropping system, drainage, etc.) were recorded on description sheets prepared by the ITRAD laboratory (Chadian Institute of Agricultural Research for Development). After the description, soil samples were taken horizon by horizon from the various open soil pits for physicochemical analysis in the laboratory. The soil classification conforms to that of the Commission for Pedology and Soil Mapping (CPCS, 1967) [8]. Permeability was determined using the “improved” Porchet method, which involves positioning three 100 mm PVC pipes around the soil profile to be infiltrated with water at a depth of 30 cm. This method eliminates lateral infiltration, which is the main source of inaccuracy in the original Porchet method, and gives results identical to those of the “Mountz double cylinder.” Measurements are taken by reading the change in water level in each pipe. The infiltration rate  $V_i$  is obtained using the following formula:

$$V_i = \frac{r}{2(t_2 - t_1)} \log \frac{(h_1 + r/2)}{(h_2 + r/2)}$$

where:

$V_i$  = water infiltration rate (in cm/h);

$r$  = radius of the PVC pipe (in cm);

$t_1$  = start time of reading;

$t_2$  = end time of reading;

$h_1$  = water level in the pipe at time  $t_1$  (in cm);

$h_2$  = water level in the pipe at time  $t_2$  (in cm).

### 2.2.2. Soil Analysis

After drying the samples in ambient laboratory air, grinding them, and sieving them through a 2 mm sieve, the methods summarized in **Table 1** are used.

**Table 1.** Soil analysis methods.

Parameters	Methods
pH	pH meter with soil/water ratio 1/2.5 Pipette
3 Fraction Particle Size Analysis	Robinson/sieving after oxidation of organic matter with hydrogen peroxide
Organic Carbon	The Walkley and Black method (1934)
Total Nitrogen	Kjeldahl
Phosphorus Bray I	Bray I
	Exchangeable Bases
Ca <sup>2+</sup> and Mg <sup>2+</sup>	Ammonium acetate and determination by atomic absorption spectroscopy
K <sup>+</sup> and Na <sup>+</sup>	Ammonium acetate and determination by flame emission spectroscopy

### 2.2.3. Soil Fertility Level in the “SANAD” Perimeter

The fertility class is the diagnostic factor used. It is determined based on:

- 1) The richness in main nutrients (nitrogen, phosphorus, potassium), organic matter, and exchangeable bases;
- 2) Nutrient availability indices (pH water and pH kCl);
- 3) Cation exchange capacity and base saturation.

Each of these parameters in the soil is assigned a rating from 1 to 5. The sum of the ratings defines the fertility class (**Table 2**).

**Table 2.** Soil fertility class standard.

Fertility Class	Very Low	Low	Medium	High	Very High
Sum of Ratings	<15.9	16 - 21.9	22 - 27.9	28 - 33.9	>34

### 2.2.4. Land Evaluation

The land evaluation method is based on [9], adapted by the ITRAD Laboratory to the agro-ecological conditions of Chad. It consists of determining the final agricultural suitability of soil units by combining partial suitability assessments, using both the limiting factor method and a subjective combination method based on the evaluator's experience and knowledge of the land. The determination of agricultural suitability relies on comparing the requirements of the intended land use types with the qualities or characteristics of the land. Final suitability classes are represented by capital letters accompanied by one or two lowercase letters indicating the major constraint(s). Partial suitability assessments are symbolized by lowercase letters. These symbols are:

S1 - s1: High aptitude.

S2 - s2: Average aptitude.

S3 - s3: Marginal aptitude.

N1 - n1: Current or temporary unfitness.

N2 - n2: Permanent unfitness.

#### 1) Soil Quality Selection

The selected soil qualities relate to irrigated and rainfed agriculture. There are six (6) criteria for evaluating soil quality:

##### a) Thermal regime (c):

This applies to the temperatures during the crop growth period. The critical terms correspond to minimum and maximum temperature values for each temperature. The average temperature during the growth period is the diagnostic factor for this soil quality. It directly influences plant growth rate.

##### b) Water availability (m):

This is influenced by climate, terrain morphology, soil type, and hydrology. Its determination is based on the following diagnostic factors: the soil's available water capacity (in mm), the length of the growth period, and the average annual rainfall.

##### c) Oxygen availability in the root zone (w):

This quality is ensured by the natural internal drainage of the soil. It is determined by field observations (soil color, redox spots, presence of groundwater, etc.). The FAO drainage class is the diagnostic factor used to assess this quality.

Class 0: Very poor drainage.

Class 1: Poor drainage.

Class 2: Imperfect drainage.

Class 3: Moderate drainage.

Class 4: Normal drainage.

Class 5: Slightly excessive drainage.

Class 6: Excessive drainage.

##### d) Nutrient availability (n):

The fertility class is the diagnostic factor used.

##### e) Rooting conditions (r):

These are determined by the effective soil depth and the ease of root penetration. The effective soil depth is the actual depth of the soil down to the intervening horizon: hardening, bedrock. The ease of root penetration is governed by textural, structural, gravel content, consistency, and the presence of shiny surfaces (slipperiness). This quality is therefore assessed based on FAO textural classes, the effective soil depth (in cm), the gravel content (%), and the soil structure and consistency.

##### f) Flood risk (i):

The frequency (probability) and duration (days) of flooding are the diagnostic factors used to assess this quality.

#### 2) Land Use Types

The objective of this study is to identify, within the designated area, soil units suitable for agricultural use under irrigation with full water control and under

rained conditions. The crops considered are as follows:

a) Under Irrigation: Cereal crops: rice, wheat, maize, sorghum; Market garden crops: tomato, onion, cabbage, potato, green bean.

b) Under Rained Conditions: Cereal crops: rice, maize, sorghum.

c) Soil Suitability: The suitability of an environment for cultivation is the extent to which the growth requirements for one or more of the selected crops are met, or not, by the specific (agro-climatic and pedological ) conditions of that environment.

A suitability class, or equipotential unit, comprises one or more mapping units with the same suitability for cultivation.

### 3. Results and Discussion

#### 3.1. Results of the Soil Survey

The study identified four taxonomic units within the perimeter. **Table 3** presents their nomenclature and their representation within the perimeter.

**Table 3.** Proportion of different soil types within the perimeter.

Soil Types	Area in ha	%
P1. Tropical Eutrophic Hydromorphic Brown Soils (BEH)	100	27
P2. Hydromorphic Soils with Low Humus Content and Surface Pseudogley (HPGS)	65	18
P3. Tropical Eutrophic Hydromorphic Vertic Brown Soils (BEHV)	125	34
P4. Vertic Vertisols (VV)	75	21
Total	365	100

It is observed that BEHVs are predominant in the area under consideration, followed by BEHs. The remaining species are present in smaller proportions. This corroborates the results of [10] on the Chari-Baguirmi plain.

##### 3.1.1. Morphological and Hydrological Characteristics of the Soils

The particle size analyses of these soils, the evaluation of their water capacity, and their infiltration capacity are summarized in **Table 4**.

**Table 4.** Particle size distribution, available water capacity, and infiltration capacity of soils.

Soil Type	Particle Size Distribution %				RU		Observations
	Depth in cm	clay	silt	sand	(mm/50cm)	Infiltration Rate (cm/h)	
BEH	27 - 60	45.1	23.5	31.3	120.2	0.02	Very Slow Rate
	60 - 78	39.2	25.4	35.2			
	0 - 32	29.3	27.4	43.1			

**Continued**

	32 - 55	43.1	23.5	33.3			
HPGS	55 - 72	43.1	21.5	35.2	117.3	0.22	Slow Rate
	0 - 20	33.3	25.4	41.1			
	20 - 43	39.2	21.5	39.2			
BEHV	43 - 72	39.2	23.5	37.2	118.2	0.3	Slow Rate
	0 - 15	35.2	27.4	37.2			
VV	15 - 30	43.1	21.5	35.2	103.4	0.18	Slow Rate

Hydromorphic soils (BEH, HPGS, BEHV) have a fine texture from top to bottom of the profile (clayey-sandy to clayey). They are firm when fresh and poorly drained. The dominant color is dark grayish-brown. They are characterized by temporary waterlogging of the surface and/or subsurface horizons. Hydromorphism is pronounced and manifests itself through redox phenomena. The structure is generally medium to coarse subangular polyhedral. The average water infiltration rate varies around 0.20 cm/h, indicating slow soil permeability. The root system and biological activity are remarkable. Vertisols have a polyhedral structure at the surface and become prismatic at depth. The texture is sandy-clayey-loamy at the surface with wide shrinkage cracks and clayey-sandy-loamy at depth. They are dark grey-brown on the surface and light olive-brown when wet at depth.

### 3.1.2. Physicochemical Characteristics of Soils

The results of the physicochemical analyses are recorded in **Table 5**.

**Table 5.** Physicochemical characteristics of soils.

	BEH	HPGS	VV	BEHV
Total Organic Matter %	0.64	0.53	0.29	0.49
Total Carbon %	0.37	0.31	0.17	0.28
Total Nitrogen %	0.03	0.026	0.017	0.02
C/N	12.33	12	10	11.44
Assimal Phosphorus	0.65	0.44	0.62	0.57
Available Potassium	53.43	54.4	51.5	53.11
Total Iron	2.15	2.39	2.22	2.25
Free Iron	1.02	0.8	0.67	0.83
Exchangeable Aluminum Al <sup>3+</sup>	0.03	0.05	0.05	0.04
Exchangeable Hydrogen H <sup>+</sup>	0.28	0.05	0.05	0.13
Electrical Conductivity $\mu$ S/cm	0.01	0.12	0.27	0.13
Calcium (Ca <sup>2+</sup> )	11.09	14.92	13.62	13.21
Magnesium (Mg <sup>2+</sup> )	3.24	3.39	5.67	4.10

**Continued**

Potassium (K <sup>+</sup> )	0.13	0.09	0.09	0.10
Sodium (Na <sup>+</sup> )	0.05	0.04	0.04	0.04
Sum of Bases (S)	14.52	18.44	19.42	17.46
(Exchange capacity) meq/100g	15.56	19.73	20.44	18.58
Saturation Ratio (S/T)%	92.67	93	95	93.56
Water pH	6.80	8.2	8.23	7.74
KCl pH	5.10	7.45	7.6	6.72

The BEHV and VV soils have organic matter levels exceeding 1%, compared to an ideal value of 1.5%, with predominantly clayey textures. In the BEH and HPGS soils, organic matter content is low, below 1%, with good to rapid decomposition ( $11.66 < C/N < 12$ ), whereas decomposition is slow in the other sites. Nitrogen content is low (0.043%) in all soil types (Table 5). Available phosphorus values are all below the 30 ppm threshold in all soils within the perimeter. This indicates that the soils are deficient in phosphorus and nitrogen. Conversely, they are well supplied with available potassium but are generally moderately poor in total and free iron.

### 3.2. Results of the Soil Fertility Assessment

After assigning scores to each soil type based on the evaluation parameters outlined above, the soils are classified as shown in Table 6.

**Table 6.** Soil fertility level assessment of “SANAD”.

Soil Type	BEH	HPGS	BEHV	VV
Score	27.75	26.5	27.75	27
Fertility Class	Average	Average	Average	Average

In crop production, soil fertility management is crucial. Indeed, fertility is the capacity of a soil to sustainably support production and is linked to the richness of the soil in mineral elements [11]. It can increase or decrease depending on farming practices. Thus, chemical soil degradation results from the depletion of nutrients. This degradation is more rapid in the Sudanian-Sahelian zone with regard to major elements. Nitrogen and phosphorus are the two key factors affecting rice production in general, according to [12]. The soils of the future development are deficient in nitrogen and phosphorus. Nitrogen deficiency leads to a reduction in the number of tillers, thus reducing the number of panicles and grains [13]. Nitrogen's action results in rapid greening and vegetation growth [14]. Phosphorus promotes better root growth, encourages more active tillering with fertile tillers, and contributes to proper grain development by increasing their nutritional value. It advances heading and positively impacts productivity [15]. Rational rice paddy management from a hydraulic perspective, the use of high-yielding varieties, and improved cultivation techniques are

all factors contributing to better yields [16]. Indeed, irrigated rice generally responds well to fertilization, especially nitrogen, if the water level is maintained from the start of the growing season. Therefore, it is essential to increase the fertility level of poor soils and compensate for the mineral elements removed by the harvest of grain and straw [14], hence the importance of fertilization. A 100 kg paddy harvest exports, depending on whether the straw is returned to the soil or not, 1.1 to 2 kg of nitrogen, 0.6 to 1 kg of  $P_2O_5$ , and 0.3 kg to 1.3 kg of  $K_2O$  [17]. Returning the straw by incorporation into the soil or as manure helps maintain the fertility of the rice paddies. In maize production, nitrogen is considered the limiting nutrient in maize influx and affects all phases of maize development and production [18]. While nitrogen deficiency limits maize yields, excess nitrogen contributes to water and air pollution. According to [19], soils used for sorghum production in sub-Saharan Africa are naturally poor in nutrients necessary for plant development. This is compounded by the combined effects of inappropriate agricultural practices and the negative impacts of climate change. In Chad, to ensure food security, populations are developing market gardening or off-season crops [20]-[22]. At the end of the rainy season, market gardening becomes a source of income for many young people and an alternative to migration. However, this sector is subject to erratic rainfall, declining soil fertility due to excessive pesticide use, pest infestations, and cultivation techniques that hinder the development of market gardening.

### 3.3. Land Assessment Results

The results of the land assessment are recorded in **Table 7**.

The four cartographic units (1, 2, 3, 4) correspond respectively to the four soil types (P1, P2, P3, and P4) whose characteristics are described in section III.1.2.

The four mapping units belong to two (2) land suitability classes, in accordance with the land evaluation method based on [9], adapted by the ITRAD Laboratory to the agro-ecological conditions of Chad. The first class, S1 - S2, is of high to medium suitability for irrigated and rainfed rice, maize, and forage sorghum. It consists of hydromorphic tropical eutrophic brown soils (BEH) and hydromorphic soils with surface pseudo-gley (HPGS). The second class, S2 - S2, has a medium suitability for all crops considered for both irrigated and rainfed cultivation. It is represented by vertic hydromorphic tropical eutrophic brown soils and vertisols. These results are similar to those obtained by [23] in the Di area of the Sourou Valley in Burkina Faso. In this study, the MCA recommended, for better soil utilization, the application of well-decomposed organic fertilizer (5 t/ha), necessary not only for improving soil structure and porosity, but also for controlling pH to avoid the tendency towards acidification in the case of rice monoculture, and furthermore, applying phosphate and nitrogen mineral fertilizer. Finally, adapting the fertilization formula to the chemical status of the soils, determined by regular monitoring of soil fertility changes under irrigation.

**Table 7.** Land assessment results.

Mapping Units	Final Suitability and Land Use	Types Area	
		ha	%
1	1) Irrigated System: S3ri for market garden crops, maize, and sorghum grain	100	27
	2) Rainfed System: S2in to maize, sorghum, and market garden crops		
2	1) Irrigated System: S2in to cereal crops (rice, maize, sorghum), to market garden crops	65	18
	2) Rainfed System: S2in to upland or lowland upland rice, to other cereals (maize, sorghum), to market garden crops		
3	1) Irrigated System: S3rw to irrigated rice; S1/S2 to other cereals (maize, sorghum), to market garden crops	125	34
	2) Rainfed System: S3rw to upland rice; S1/S2 to other cereals (maize, sorghum)		
4	S3 to all crops considered	75	21
365	100		

#### 4. Conclusion

The objective of this study is to determine the nature of the soils within the “SANAD” perimeter, their respective physicochemical constraints, and their suitability for irrigated and rainfed crops. Soil surveys revealed four (4) soil types: Hydromorphic Tropical Eutrophic Brown Soils (BEH), Hydromorphic Soils with Low Humus and Surface Pseudogley (HPGS), Vertic Hydromorphic Tropical Eutrophic Brown Soils (BEHV), and Vertic Vertisols (VV). BEHV and VV soils exhibit organic matter content exceeding 1%, compared to an ideal value of 1.5%, with predominantly clayey textures. In BEH and HPGS soils, organic matter content is low, below 1%, with good to rapid decomposition ( $11.66 < C/N < 12$ ). BEH and HPGS soils show the best potential, ranging from high to medium suitability for irrigated and rainfed rice, maize, and sorghum cultivation. BEHV and VV soils are suitable for market garden crops and other cereals, particularly maize and sorghum. Finally, the results show that these soils, identified within the developable area, belong to the medium fertility class. These results support the recommendation of applying well-decomposed organic fertilizer (5 t/ha), which is necessary not only to improve soil structure and porosity but also to control pH and prevent acidification.

## Conflicts of Interest

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

## References

- [1] Roose, E. (2018) Restauration de la productivité des sols tropicaux et méditerranéens: Contribution à l'agro écologie. IRD-Éditions.
- [2] Devèze, J., Jullien, J. and Papazian, V. (2003) Grands aménagements hydro-agricoles d'Afrique subsaharienne: Poursuivre les évolutions institutionnelles. *Afrique Contemporaine*, **205**, 193-203. <https://doi.org/10.3917/afco.205.0193>
- [3] Bangoura, S. (2001) Les techniques de collectes des eaux et la durabilité. <https://agris.fao.org/search/en/providers/122621/rec-ords/6477622b5eb437ddff786050>
- [4] Bruinsma, J. (2009) The Resource Outlook to 2050: By How Much Do Land, Water and Crop Yields Need to Increase by 2050? Food and Agriculture Organization of the United Nations, Economic and Social Development Department.
- [5] MAAPRAT-CGAAER (2012) L'eau et la sécurité alimentaire. Face au changement global: Quels défis, quelles solutions? Contribution au débat international, Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'aménagement du territoire-Conseil général de l'alimentation, de l'agriculture et des espaces ruraux.
- [6] Troy, B., Bachelier, B., Jaskulké, E. and Mangé, P. (2008) Document d'orientation stratégique de la fondation FARM sur l'eau 2008-2010. Fondation FARM.
- [7] FAO (1994) Directives pour la description des sols, édition révisée.
- [8] CPCs (1967) Classification française des sols. Inéra Paris Grignon Edition, 87.
- [9] FAO (1976) Évaluation des terres pour l'agriculture irriguée: Directives.
- [10] ORSTOM (1958) Etude pédologique-campagne 1958, 86 p.
- [11] Philippe, L.-D. (1996) Gérer la fertilité des terres dans les pays du sahel: Diagnostic et conseil aux paysans. GRET, 397 p.
- [12] Traoré, K. and Toé, M.A. (2008) Capitalisation des initiatives sur les bonnes pratiques agricoles au Burkina Faso. 99 p.
- [13] Bandaogo, A. (2010) Amélioration de la fertilisation en riziculture irriguée dans la vallée du Kou à travers la technologie placement profond des granules d'urée, mémoire. DEA Université Polytechnique de Bobo Dioulasso, 66.
- [14] Dobelmann, J.P. (1976) Riziculture pratique (Technique vivantes. 1. Riz irrigué). Presses Universitaires France, 220 p.
- [15] Adam, Y.N. (2000) Étude d'une fumure à base de burkinaphosphate sur le riz irrigué à la Vallée du Kou, dans l'Ouest du Burkina Faso. Mémoire de fin d'études de l'IDR, Université Polytechnique de Bobo Dioulasso, 73 p.
- [16] CIRAD-GRET (2006) Mémento de l'agronome. Jouv.
- [17] Camille, C. (1997) Les matériels de fertilisation et de traitement des cultures: Technologies de l'Agriculture 1ère (Vol. 4/5, Collection éd'n). FORMAGRI, 343 p.
- [18] Nda, H.A., Kouakou, C.K. and N'cho, A.L. (2022) Gestion post-récolte du maïs (*Zea mays* L.) au Nord de la Côte d'Ivoire: Pratique paysanne et typologie des systèmes de stockage. *International Journal of Biological and Chemical Sciences*, **16**, 2658-2672.
- [19] Somda, B.B., Ouattara, B., Serme, I., Pouya, M.B., Lompo, F., Taonda, S.J.B., et al. (2017) Détermination des doses optimales de fumures organo-minérales en micro-dose dans la zone soudano-sahélienne du Burkina Faso. *International Journal of Bi-*

*ological and Chemical Sciences*, **11**, 670-683. <https://doi.org/10.4314/ijbcs.v11i2.11>

- [20] Benoit, G. (2016) Eau, agriculture et changement climatique: Statuquo ou anticipation. Rapport No. 16072, 66.
- [21] Apollin, F. (2016) Rapport d'activités: Agronomes et vétérinaires sans frontières. 17.
- [22] Leyronas, S. (2016) Notes Techniques/Technical Reports: Gestion des ressources en eau souterraines comme biens communs. 236.
- [23] MCA (2010) Etudes techniques d'aménagement de 2033ha du périmètre aménageable de Di dans la vallée du Sourou, Burkina Faso.