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Performance Status of the Bongor Rice-Growing Area, Mayo-Kebbi East Province, Chad: Observations and Outlook

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Abstract: An assessment of the performance of the Bongor rice-growing area in the Mayo-Kebbi East province of Chad over two growing seasons (dry season and rainy season) was conducted in 2025. Three methods were used: soil surveys and analysis to assess the fertility level of plot B, diagnostic analysis based on farmers' perceptions within the plot, and finally, evaluation of performance indicators for plot B based on a set of indicators derived from the diagnostic phase. The results show that upon its creation in 1964, the area used technical guidelines disseminated by the National Office for Rural Development (ONDR) under the supervision of Chinese cooperation. Thus, the judicious use of fertilizers and pesticides, irrigation management, and the introduction of high-yield fertilizers have enabled agricultural yields to reach up to 8 t/ha in 1978, compared to 4 t/ha in 2024. Soil analyses confirm a deficiency in phosphorus (P < 30 ppm) and nitrogen (N < 5%). The high average C/N ratio (13) suggests low organic matter mineralization in these soils and necessitates corrective action to increase mineral nutrient uptake.

Key words: Rice-growing area, Mayo-Kebbi East, soil fertility, performance, efficiency.

1. Introduction

Chad, a landlocked country in Central Africa, covers an area of 1,284,000 km² and has a population of 15,231,625 [1], representing a population density of 8.7 inhabitants per square kilometer and a growth rate of 3.5%. Seventy-eight percent (78%) of its inhabitants live in rural areas and derive most of their food and nutritional products from agricultural, forestry, livestock, and fishing activities. These agricultural, forestry, livestock, and fishing production systems are characterized by very limited performance due to their vulnerability to hazards, land tenure issues, soil fertility loss, and low levels of modernization and intensification [2]. Specifically, in the agricultural sector, there is a lack of availability and accessibility of agricultural inputs, particularly certified seeds and mineral fertilizers, as well as limited use of modern agricultural equipment (carts, plows, tractors, tillers). This is compounded by the limited capacity for storing and preserving agricultural products, resulting in significant post-harvest losses [3]. From independence to the present day, Chadian agriculture has been dependent on rainfall [4, 5]. Over the years, faced with the dual challenges of rainfall variability and food insecurity, the intensification of irrigated agriculture has become essential to address the progressive decline in agricultural production and yields. The Bongor rice-growing area, established in 1965 [5], addresses this objective. The aim of this study is to evaluate the performance of this rice-growing area in the context of climate change, where the agricultural sector is struggling to modernize and remains largely dependent on climatic hazards. It also suffers from underfunding and insufficient reforms. Agricultural production fluctuates wildly. Almost every other year there is a cereal deficit, two out of five a fodder deficit, and lean seasons are becoming increasingly longer

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than usual for vulnerable groups [3]. The situation worsens during crises when affected households, lacking humanitarian assistance, resort to desperate measures such as rural exodus, begging, and debt to cover food needs and access other factors of production. The impoverishment and weakening of households make them dependent on markets and prevent them from coping with recurring crises. The PRP-AGIR [6] estimates that more than 20% of households suffer from chronic undernourishment.

2. Material and Methods

2.1 Material

2.1.1 Location of Locker B

The city of Bongor is located in southwestern Chad, between the 9th and 11th degrees of north latitude and the 14th and 16th degrees of west longitude (Figure 1). With a population of 553,027 in 2009, it is one of the most densely populated areas of Chad, with an average population density of 40 inhabitants per km². Established in 1965 under a cooperation agreement between the Republic of Chad and Taiwan, the rice-growing perimeter, also known as “Plot B”, is located in Fressou, in the Telmé district, 18 km north of Bongor. It covers an area of 500 hectares under the city’s complete control. The first canal comprises 180 plots, and the five others each comprise 360 plots, for a total of 1,980 plots, or 495 hectares.

2.2 Methods

Three methods were combined: (i) soil survey and analysis, (ii) interviews followed by a physical diagnosis of cell B, and (iii) evaluation of performance indicators.

2.2.1 Soil Survey and physicochemical Analysis of soils

2.2.1.1 Soil Survey

The soil survey of Bongor’s Plot B used the transects method. A transect extending from east to west, encompassing all soil types in Plot B, was established. Soil profiles were opened along the entire transect and described according to FAO guidelines [7]. Colors were assigned using the Munsell Color Code. After description, soil samples were collected horizon by horizon from the various open soil pits for physicochemical analysis in the laboratory. Data on the profile and its surroundings (depth, color, structure, texture, gravel content, biological activity, vegetation and/or cropping system, drainage, etc.) were recorded on descriptive sheets prepared by the ITRAD laboratory. After laboratory analysis, the soils were identified and classified according to the system of the Commission for Soil Classification and Mapping [8]. Permeability was determined from the water infiltration rate in the soils, measured using the Muntz method.

Fig. 1 Location map of Bongor cell B.

2.2.1.2 Physicochemical Analysis of Soils

After drying the samples in ambient air in the laboratory, grinding them, and sieving them through a 2 mm sieve, the methods summarized in Table 1 were used. The various procedures are documented in the ITRAD database, whose 1990 standards were also used to interpret the analytical results.

The available water capacity (AWC) is determined by the formula below.

AWC = (HpF2.5 - HpF4.2) x Z x da / 100

Where:

* AWC = Available water capacity (mm);

Da = Apparent density (= 1.7 on average for soils in Chad);

* Z = Thickness of the horizon in the first 50 centimeters;

* HpF2.5: Soil moisture at field capacity in %;

* HpF 4.2: soil moisture at permanent wilting point in %.

2.2.2 Soil Fertility Level Bongor's Plot

The fertility class is the diagnostic B *in the Perimeter* factor used. It is determined based on:

- The richness in main nutrients (nitrogen, phosphorus, potassium), organic matter, and exchangeable bases;
- Nutrient availability indices (pH water and pH kCl);
- 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).

2.2.3 Interviews and Physical Assessment of Plot B

The Participatory Action Research (PAR) approach was chosen for this study. It involved:

- Interviews and focus groups, which allowed for establishing a certain level of familiarity and trust with the producers—an atmosphere necessary for obtaining honest information about their levels of satisfaction and expectations regarding the water management of the irrigation perimeter and the support provided by ANADER;
- Visits and inspections of agricultural infrastructure;
- Flow measurements at the head and at each hydraulic node to determine network efficiency;
- Determination of irrigation parameters such as application rate, application efficiency, distribution uniformity, etc.;
- Measurements on the various canals, drains, and structures using a measuring tape to determine the ceiling width, depth, and dimensions of ancillary structures;
- Identify any anomalies present in the networks;
- Locate the various points in the network;
- Photograph the various structures within the perimeter.

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	Walkley and Black method (1934)
Total Nitrogen	Kjeldahl
Phosphorus Bray I	Bray I
Exchangeable Bases	
Ca2+ et Mg2+	Ammonium acetate and determination by atomic absorption spectroscopy
K+, Na+	Ammonium acetate and determination by flame emission spectroscopy

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 Formulation of Diagnostic Indicators

To process this information, we selected the following diagnostic indicators.

Degree of Sanction Application (DAS)

DAS = (NSE / NSP) x 100

Where:

NSE = number of sanctions enforced;

NSP = number of sanctions adopted at the General Meeting.

The DAS indicator provides information on the application of the internal regulations.

Equity in Water Distribution (eq)

Eq = NEN / NEE

Where:

NEN = number of dissatisfied operators;

NEE = number of operators in the sample.

Eq provides information on cooperation in respecting the water rotation schedule and distribution planning.

Water Turnover Monitoring (STE)

STE = QSTE / NTQ

Where:

QSTE = number of irrigations districts or blocks not adhering to the water turnover schedule;

NTQ = total number of irrigation districts.

STE measures satisfaction with collaboration regarding adherence to the water turnover schedule.

Field Leveling Control (MPP)

MPP = PBP / NP

Where:

PBP = number of well-leveled plots;

NP = total number of plots.

The MPP indicator provides information on training related to agricultural topics.

Overall Irrigation Dose (DG)

DG = Vpi (m^3) / 10 x Se (ha)

Where:

Vpi = volume withdrawn for irrigation;

Se = cultivated area.

The DG indicator provides information on monitoring water withdrawals for irrigation based on cultivated areas.

2.2.4.1 Selection of Performance Indicators for the Irrigation and Drainage System

Based on data collected through interviews and document review, we can evaluate the following frameworks:

Agronomic Framework

The performance indicators to be considered for evaluating the agronomic aspects of irrigation are:

Yield (R)

R = (Production (tonnes)) / (Sown Area (ha))

The R indicator provides information on determining the target production level at the beginning of the season; monitoring production and sown areas.

Cultivation Intensity (CI)

CI = (annual sown area) / (developed area) * 100

The CI indicator provides information on monitoring production and sown areas.

Production per unit of irrigation water consumed (PbIr)

PbIr = (gross production) / (volume of irrigation water)

PbIr allows for the evaluation of production monitoring and irrigation water withdrawal.

Hydraulic Framework

We will consider the following indicators to determine irrigation performance within the perimeter of Basin B. These are:

Calculation of the flow rate (Q) transported by the Primary Canal (PC)

Based on the formula: Q = V*S, with S = y*(b+m*y)

Institutional Framework

Water Fee Collection Rate (WFR)

WFR = (Total amount collected for the season) / (Total amount due)

Water Fee per Unit of Gross Production Value (GPRV)

GPRV = (Water Fee collected for the season) / (Gross Production Value)

Water Fee per Unit of Net Production Value (NPRV)

NPRV = (Water Fee collected for the season) / (Production Value - Costs)

GPRV and NPRV allow us to assess the collection and management of water fees.

3. Results and Discussion

3.1 Soils Survey Results

The study identified four taxonomic units in grid cell B of Bongor. Table 3 presents their nomenclature and representativeness within.

It is observed that HPGS are predominant in cell B, followed by BEHV. The remaining particles are present in smaller proportions. This corroborates the results of ORSTOM [9] on Cell "A" north of Bongor.

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.

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 Physico-Chemical Characteristics of Soils

BEHV and VV soils have organic matter levels exceeding 1%, compared to an ideal value of 1.5%, with predominantly clayey textures. In BEH, HPGS, and BEF soils, organic matter content is low, below

Table 3 Proportion of different soil types in cell B.

Soil Types	Area en ha	%
P1 Tropical Eutrophic Hydromorphic Brown Soils (BEH)	23	4.6
P2 Hydromorphic Soils with Low Humus Content and Surface Pseudogley (HPGS)	252	50.4
P3 Tropical Eutrophic Hydromorphic Vertic Brown Soils (BEHV)	195	39
P4 Vertiginous vertisols (V V)	30	6
Total	500	100

Table 4 Particle size distribution, available water capacity, and infiltration capacity of soils in cell B.

		Particle size distribution **%**			**RU**		
Soils types	**depth in cm**	**clay**	silt	**Sand**	**(mm/50cm)**	Infiltration Rate **(cm/h)**	**Observations**
BEH	27-60	45.1	23.5	31.3	120.2	0.02	
	60-78	39.2	25.4	35.2			Very Slow Rate
	0-32	29.3	27.4	43.1			
HPGS	32-55	43.1	23.5	33.3	117.3	0.22	
	55-72	43.1	21.5	35.2			Slow Rate
	0-20	33.3	25.4	41.1			
BEHV	20-43	39.2	21.5	39.2	118.2	0.3	
	43-72	39.2	23.5	37.2			Slow Rate
	0-15	35.2	27.4	37.2			
VV	15-30	43.1	21.5	35.2	103.4	0.18	

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 4). Available phosphorus levels are all below the 30-ppm threshold in all soils within the perimeter. This indicates that the soils in cell B are deficient in phosphorus and nitrogen. Conversely, they are well supplied with available potassium but are generally moderately poor in total and free iron.

The exchangeable base values are almost identical in Table 5, likely due to the hydromorphism of the soils in relation to their texture. Exchangeable calcium and magnesium levels are low, while potassium and sodium levels range from low to very low. Overall, the soils in cell B are neutral to slightly acidic. This result is similar to that obtained by Moussa [10] at the Djarmaya site in Chad. Based on the CEC values, the soils in the area have a high capacity to retain bases from their internal mineralization and from external inputs through mineral fertilization. The high CEC level (Table 4) in the hydromorphic soils and vertisols is related to their predominantly clayey texture. Electrical conductivity values are high (3.8 to 5 ds/m), suggesting a risk of salinization. Indeed, high salt levels in soils or irrigation water are a major environmental concern and a serious problem for agriculture in arid and semi-arid regions. Excess salt in the soil affects germination, seedling growth and vigor, the vegetative phase, flowering, and fruiting to varying degrees [11-13], ultimately leading to reduced yields and lower crop quality. Furthermore, a study conducted on the genus Phaseolus demonstrated that the variability in salinity tolerance among species largely stems from a high PR/PA (root biomass/above-ground biomass) ratio [14].

Table 5 Physico-chemical characteristics of soils.

	BEH	**HPGS**	BEHV	VV
Total Organic Matter %	0.663	0.58	1.004	1.04
Total Carbon %	0.385	0.336	0.582	0.864
Total Nitrogen %	0.0326	0.028	0.046	0.0665
C/N	12	11.66	12.66	13
Assimal Phosphorus	7.99	2.433	8.37	4.4
Available Potassium	109.83	49.91	92.06	104.55
Total Iron	13.4	14.4	15.86	14.59
Free iron	2.56	3.23	2.68	3.04
Exchangeable aluminum Al3+	0.29	0.29	0.28	0.3
Hydrogène échangeable H+	0.09	0.09	0.08	0.09
Electrical conductivity µS/cm	16.4	18	18.84	18.03
Calcium (Ca2+)	21.1	22.9	23.29	23.17
Magnésium (Mg2+)	77.7	78.3	81	78
Potassium (K+)	6.62	7.02	7.37	7.41
Sodium (Na+)	5.65	6.23	6.68	6.42
Sum of bases (S)	3.8	4	4	5
(Exchange capacity) méq/100g	2.46	2.99	2.46	2.85
Saturation ratio (S/T) %	1.61	1.72	1.97	2.1
Water pH	0.65	2.57	0.80	0.73

Table 6 Evaluation of soil fertility levels in cell B.

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

3.2 Evaluation of Soil Fertility in Cell B

After assigning ratings to each soil type based on the evaluation parameters outlined above (Table 5), the soils in cell B are classified as shown in Table 6.

In crop production, soil fertility management is crucial. Indeed, fertility is the capacity of a soil to sustainably produce crops and is linked to the richness of the soil in mineral elements [15]. 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 main factors affecting rice production in general, according to Traoré and Toé [16]. Plot B is experiencing nitrogen and phosphorus deficiencies. This may explain the yield decline in the area. Nitrogen deficiency is generally considered the main cause of yield reductions [17, 18]. Nitrogen deficiency leads to a reduction in the number of tillers, thus reducing the number of panicles and grains [19]. Nitrogen's effects result in rapid greening and vegetation growth [20]. Phosphorus promotes better root growth, encourages more active tillering with fertile tillers, and contributes to proper grain development by increasing their nutritional value. It also advances heading and positively impacts productivity [21]. Rational management of rice paddies from a hydraulic perspective, the use of high-yielding varieties, and improved cultivation techniques are all factors contributing to higher yields [22]. Indeed, irrigated rice generally responds well to fertilization, especially nitrogen, if the water level is maintained from the beginning of cultivation. For better soil utilization, an application of well-decomposed organic fertilizer (5t/ha) is necessary not only to improve soil structure and porosity, but also to control pH to avoid the tendency towards acidification in the case of rice monoculture; to apply phosphate and nitrogen mineral fertilizers and finally to adapt the fertilization formula to the chemical status of the soils determined by regular monitoring of the evolution of soil fertility under irrigation.

3.3 Results of the Interviews and Physical Diagnosis of Cell B

3.3.1 Results of the Physical Diagnosis of the Cell

This consisted of identifying and photographing the various anomalies existing on the structures and equipment within the perimeter.

3.3.2 Results of Interviews with Stakeholders

- Summary of Producers' Viewpoints

Enrolled in cooperatives, the villagers of the villages surrounding the Casier, also known as the local people, still refer to customary law and strongly reject the new land law, which they perceive as a system of dispossession. The views of 36 producers surveyed out of a carefully selected group of 820 are summarized as follows.

According to the producers, the soil is "exhausted" and yields are declining, with less than 3 tons per hectare. Fertilizer is never sufficient because its price is very high.

In terms of water management, the off-season harvest is carried out with complete control, while the rainy season harvest is done with supplemental irrigation.

The irrigation and drainage network exists but is poorly maintained and degraded in places. The producers blame the management committee, which they say doesn't allocate sufficient resources for repairs and maintenance. "And yet", adds Mr. Samangassou, a producer, "we pay the fee in full, that is, 120,000 CFA francs in the off-season and 50,000 CFA francs in the rainy season. Everyone has to do their job. The machines are often broken down, and the water allocation schedule isn't respected. Despite this poor quality of service, we don't receive any reduction in the fee payment. How can you expect us not to siphon water? How can you expect us to participate voluntarily in network maintenance? Furthermore, the management committee can't guarantee us a purchase price; we're at the mercy of unscrupulous traders who dictate their prices."

- Management Committee Viewpoints

The management committee exists with statutes and regulations governing its operation. According to Vatvounsia Foura, president of the Basin B Management Committee, "the visible problem is the silting up of the Logone River, which has drastically reduced the flow of water, especially in front of the pumping station. This may be an effect of climate change." The water rotation system exists and is five days long, the president acknowledges. Frequent breakdowns of the machinery lengthen it, and the farmers are impatient. He believes the aging machinery results in high maintenance costs. The collected fees barely cover maintenance and operating costs (diesel fuel, lubricants), while the farmers are now refusing to participate in work of common interest. The management committee must make greater efforts to maintain the drainage network; when it can no longer do so, the network remains in a state of disrepair and overgrown with vegetation, a situation everyone is aware of. Furthermore, we are overwhelmed by lobbying from retailers who reject our price proposals, while the producers themselves do not support us. They say, "We don't have the same

1. Canal panel (first area) overgrown with grass.

2. Canal panel (first area) detached.

3. Tertiary canal (earthed).

4. Water level in the drain.

5. Disorder in the pumping station.

6. Mobile pumping station not functioning.

Fig. 2 Photos taken in February 2025 by Epolyste A.

Table 7 Results of diagnostic indicators.

Diagnostic indicators					Performance Indicators				
DAS	Eq	STE	MMP	DGm^3/ha	RVPB%	RR%	PBIr	R	IC
0%	66%	66%	27%	12800m^3/ha	1.6%	100%	0.46Kg/m^3	3.95T/ha	98 et 100%

problems; everyone sells according to their own situation". The management committee's working capital comes from water fees. This fund is intended for the maintenance of the hydraulic infrastructure within the area. The fees are deducted directly when input loans are repaid. This ensures that all producers pay their fees regularly.

- Viewpoint of the Agricultural Advisors of the National Agency for Rural Development (ANADER)

Producers are not adhering to crop calendars, specifically the sowing and transplanting schedule. This impacts irrigation planning. The problem, he explains, is that crops' water needs vary with their stages of development. When there is a significant disparity in the cycle, it is difficult to meet the crops' actual needs, and production suffers. "We are working to change behaviors, but it takes time", he adds. As long as producers do not follow the technical guidelines, production will be hampered in the B irrigation scheme. Added to this are the outdated equipment, with recurring breakdowns of pumping stations, and the problem of marketing agricultural products. A major consequence of this is that the private sector for supplying inputs and credit is not developing as rapidly as anticipated.

3.4 Results of Diagnostic and Performance Indicators

The results obtained from the diagnostic and performance indicators are summarized in Table 8.

The volume withdrawn for irrigation (Vpi1) amounts to Vpi1 = 1500 mm, i.e., 15,000 m³/ha, or 8,100,000 m³/season. Regarding the water rotation, producers in block #3 are dissatisfied with the rotation and complain about the behavior of producers in the first two blocks who manipulate the sluice gates for uncontrolled water withdrawals. The rate of non-compliance with the water rotation (STE) is therefore STE = 66.66%. Two-thirds of the producers do not follow the water rotation.

Regarding equity in water distribution (eq), based on the sample interviewed, dissatisfaction with the equity of water distribution is evident. The dissatisfaction rate is: eq = 66%. In addition, the distribution of water, which should be from downstream to upstream on a tertiary channel, is not being respected by the producers. The overall irrigation dose (DG), calculated by the AMVS, gives a total dose of DG = 1280 mm.

The leveling rate: The physical assessment determined that one in three plots is poorly leveled. This gives us a "poor" leveling rate of 33%.

The relative water supply (RWS) was calculated exclusively for rice, which is the main off-season crop. The value obtained is RWS = 1.3.

The flow rate, calculated from the average water velocity in the primary canal, is 83 l/s.

The yield: This was calculated from the data provided by the 36 producers surveyed. The crop considered is rice, which is uniformly cultivated during the winter season. The yield obtained is R = 3.95 t/ha; the technical advisor gives 4 t/ha.

During the rainy season, all 500 ha are sown, corresponding to a cropping intensity (CI) of 100%. However, during the 2024 off-season campaign, block A is 100% sown, while 7 ha in block B and 3 ha in block C were not sown, resulting in a cropping intensity (CI) of 490/500 = 0.98, or 98%. For the year 2024, an average of 99% is obtained.

Gross Production per Unit of Irrigation Water (PbIr): for maize, the data provided by the technical advisor allowed us to determine this, assuming of course that the entire area is sown. The result obtained is: PbIr = 0.46 kg/m³. The recovery rate for maintenance fees is 100% for rice. For maize, it depends on the

Table 8 Comparison of diagnostic and performance indicators with PMI-Chad/IMMI reference values.

Values of the perimeter of Locker B	Values for the southwest zone of Chad (references) according to PMI-Chad	Observations
MPP = 33%	MPP_0 = 100%	The 33% indicates the number of poorly leveled plots, while the reference 100% indicates what should be well leveled.
STE = 66%	STE_0 = 5%	The failure to follow the water rotation schedule should not exceed 5%; it is 66% at Locker B
Eq =66%	Eq_0 = 10%	The rate of producers dissatisfied with fairness should not exceed 10%; it is 66% in Cell B
DAS = 0%	DAS_0 = 100%	The OP is unable to apply the sanctions in accordance with the organization's rules.
DG = 1280 mm in the off-season	DG_0 = 800 mm for off-season market gardening	The overall dose is higher than the average required, which justifies the water requirements of crops in SS

number of plots under cultivation. The Water Fee and Gross Production Value (RVPb) for maize is 1%, while for rice it is 1.1%. The Water Fee and Net Production Value for the 500 ha (planted with rice) is 1.6%.

During the rainy season, all 500 hectares are cultivated, corresponding to a cropping intensity (CI) of 100%. However, during the 2013 off-season, block A was 100% cultivated, while 7 hectares in block B and 3 hectares in block C were not, resulting in a cropping intensity (CI) of 490/500 = 0.98, or 98%. For 2013, the average was 99%.

Interviews revealed that no sanctions have ever been imposed or enforced. This reflects the lack of application of the internal regulations within the area.

The sample interviewed consisted of 36 producers (twelve per block). Eight producers from Block A, eight from Block B, and eight from Block C—a total of 24 producers—are dissatisfied with the fairness of water distribution. In other words, 66% of producers are dissatisfied with the fairness of water distribution. This 66% failure to adhere to the water rotation schedule is often due to frequent breakdowns at pumping stations. When a breakdown lasts two or three days, the plot that was supposed to be irrigated on the fifth day of the normal rotation must wait until the seventh or eighth day. Therefore, if this plot is near the canal that was meant to supply it, the producer prefers to take a shortcut by siphoning water as soon as the station is back online while waiting for their turn. FINA, a producer from Block C, said on this subject: "When you're hungry, you scramble to find food; the method doesn't matter, as long as you find food". Ten out of 36 plots are poorly prepared. Producers use a technique that involves dividing the plot into sections of roughly uniform height. This practice obviously reduces the area available for cultivation, and therefore could contribute to a decrease in production on the plot.

4. Conclusion

The major constraints on soil productivity in tropical regions are largely linked to the low level of soil fertility. This study aimed to contribute to increasing rice production in the "Plot B" irrigated area of Bongor (located in the Logone Valley in Chad), through soil sampling and the identification of fertility levels, combined with the assessment of diagnostic indicators in the field. This allowed us to determine the mineral elements limiting production in the area, for which soil types were identified. The results showed that phosphorus and nitrogen are the limiting elements for rice production, in addition to the high level of salinization. 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. A fertilization formula tailored to the soil's chemical status, determined by regular monitoring of changes in soil fertility levels under irrigation, is also recommended. These two recommendations should be accompanied by an information, education, and communication campaign on adhering to the technical guidelines for each plot, which helps avoid extending pumping time and increasing production costs.

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