


# Integrated Approach for the Agroecological Rehabilitation of Bauxitic Soils: Maize-Groundnut Intercropping for Rural and Economic Food Resilience

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## Abstract

This study assesses the agronomic, social, and environmental feasibility of rehabilitating a former bauxite mining site into agricultural land in Sangarédi, Guinea. The experiment was based on maize-groundnut intercropping, supported by an integrated organo-mineral amendment plan. This plan combined agricultural lime, composted poultry manure, superphosphate ( $P_2O_5$ ), and NPK (17-17-17) to restore degraded soil fertility and sustainably improve yields. Results—7.88 tons of maize, of which 6.56 were marketed, 1.20 consumed locally, and only 0.12 lost—reflect an encouraging dynamic of progress, despite yield gaps of 13.50% for maize and 17.33% for groundnut compared to regional averages. The agroecological approach adopted contributes to biodiversity regeneration, restoration of soil ecological functions, and food and economic resilience for local communities. This reproducible model, adapted to Guinean agroclimatic conditions, offers perspectives for extension to other mining zones facing similar challenges.

## Keywords

Agroecological Rehabilitation, Degraded Bauxite Soils, Maize-Groundnut Intercropping, Rural Food Resilience, Local Governance, Mining Rehabilitation

## 1. Introduction

Guinea, a West African country with significant agroecological potential, derives a substantial share of its revenue from mining activities, particularly bauxite, of

which it is the world's second-largest producer [1]. The mining sector contributes between 15% and 20% of GDP, accounts for more than 80% of export earnings, and nearly one-third of government revenue [2]-[4].

This extractive dynamic, concentrated in the prefecture of Boké, exerts considerable pressure on arable land, a situation further aggravated by climate change and soil degradation. Yet, agriculture remains the backbone of livelihoods: 84% of Guinea's working population depends on farming, and 99% of agricultural households in Boké practice subsistence agriculture or livestock rearing [5].

In the urban municipality of Sangarédi, the epicenter of bauxite mining, rehabilitation of former mining sites remains largely unexplored. Current practices prioritize reforestation, which, while ecologically beneficial, does not guarantee soil fertility restoration or address the food security needs of local communities.

Faced with these limitations, ecological soil engineering offers simple and context-appropriate alternatives capable of regenerating ecological functions while simultaneously enhancing soil productivity. This study therefore tests the agronomic and social feasibility of converting a former mining site into agricultural land through maize-groundnut intercropping combined with an organo-mineral amendment plan. The central hypothesis is that agroecological conversion of degraded bauxitic soils in Sangarédi is possible and contributes to both food security and the socio-economic resilience of local communities.

## 2. Materials and Methods

### 2.1. Site Presentation

This study was conducted in the urban municipality of Sangarédi, located 72 km from Boké prefecture, specifically in Hamdallaye village, a former bauxite quarrying zone that ceased operations in 2014 and resumed in 2020 during the rainy season (June-September). Sangarédi lies at 10° 36'28"N latitude and 14° 17'54"W longitude, covering a surface area of 2837 km<sup>2</sup>.

The tropical climate is characterized by two alternating seasons: a six-month rainy season (June-November) influenced by monsoon winds, and a six-month dry season (December-May) dominated by harmattan winds. Annual rainfall ranges between 1200 and 3200 mm, while temperatures vary from 15°C to 45°C. The relief is rugged, dominated by ferruginous plateaus locally known as "*bowed*." Containing nearly two-thirds of the world's bauxite reserves, this area is a major mining hub. Vegetation cover consists of trees and herbaceous species interspersed with small forest patches [6].

Soil analyses were conducted at the Soil Laboratory of the Guinean Agricultural Research Institute (IRAG), Foulayah (Kindia), in April 2020.

### 2.2. Materials

The maize and groundnut varieties used were those recommended by local technical services and beneficiaries, namely "Petra" (maize) and "Local White" (groundnut). Soil amendment and fertilization involved the application of quick-

lime, composted poultry manure, and NPK 17-17-17. Standard laboratory reagents were employed for chemical analyses.

## **2.3. Methods**

### **2.3.1. Soil Rehabilitation**

Following the closure of mining excavations and the preliminary leveling of the site, an agro-pedological analysis commissioned by the municipality of Sangarédi and conducted by the Central Laboratory of the Guinean Institute of Agronomic Research (IRAG) [7] revealed a highly acidic soil condition, with a pH of 4.13 prior to rehabilitation.

To correct this acidity, the topsoil removed at the beginning of mining operations—stored and exposed to weathering for fourteen years—was reincorporated after being mixed with lime at a rate of 2 t/ha. This operation aimed to adjust soil pH, improve nutrient availability, and enhance root development, while avoiding direct contact between lime and clay that could inhibit phosphorus availability. Prior to incorporation, large residual rock fragments were removed.

In addition, a complementary layer composed of 25 cm of clay—applied to improve texture, enhance cation exchange capacity (CEC), and increase water retention [8]—and 25 cm of black soil, distinct from the original topsoil and rich in organic matter, was uniformly spread across the site and thoroughly mixed. Clay was incorporated homogeneously with the back soil to ensure structural stability and avoid the formation of compacted layers, while the organic-rich substrate boosted microbial activity and reinforced biological fertility [9]-[11]. Deep tillage was then performed to homogenize the soil profile, prevent horizon stratification, and ensure optimal integration of the amendments. All amendments were applied in January 2019. Prior to incorporation, large residual rock fragments were manually removed.

Subsequently, the rehabilitated soil was placed under fallow for fifteen months (February 2019 - April 2020). This agronomic practice, recognized by FAO [10] and Lal [11], improves soil structure through microbial action, stimulates organic matter mineralization, and enhances the ecological resilience of degraded soils. The fallow period was intended to promote the gradual recovery of microbial activity and biological regeneration, both essential for restoring fertility and ensuring sustainable crop production. At the end of this period, microbial activity was assessed to evaluate the effectiveness of the rehabilitation process.

### **2.3.2. Site Performance Assessment**

Site performance was assessed through visual observation of vegetation regrowth and evaluation of soil quality.

#### **1) Visual Assessment of Grass Cover and Sampling**

In October 2019, nine months after fallowing at the end of the rainy season, a visual assessment was conducted to evaluate vegetation recovery (grass cover), serving as an indirect indicator of soil microbial activity.

To assess the quality of rehabilitated soil intended for maize and groundnut

cultivation, samples were collected on April 18, 2020 using a rigorous protocol.

## 2) Soil Sampling Protocol

Soil samples were collected following international agronomic recommendations [10] [12]. Sampling was performed at a depth of 0 - 20 cm, corresponding to the arable horizon, at fifteen points distributed representatively across the site. The points were selected randomly by following a zigzag path to ensure representativeness [13]. Individual samples were combined to form a homogeneous composite sample, free of debris, from which subsamples were retained for enrichment and sowing tests and agro-pedological analysis. This protocol ensured reliability, reproducibility, and compliance with international standards for soil resource surveys [12].

## 3) Maize and Groundnut Behavior Test in Different Substrates

To evaluate the behavior of maize and groundnut in various substrates, a quantity of 10 kg from this composite was retained for enrichment and sowing tests.

This amount was divided into twelve bags:

- Nine bags were enriched according to different combinations,
- Three bags were kept as unenriched controls.

Each bag was numbered, dated, and identified according to the type of enrichment applied. The modalities are presented in **Table 1** below.

**Table 1.** Enrichment modalities of rehabilitated soil.

Bag Numbers	Substrate Composition	Tested Crops
1 - 3	Rehabilitated soil + poultry manure	Maize + Groundnut
4 - 6	Rehabilitated soil + NPK fertilizer (17-17-17)	Maize + Groundnut
7 - 9	Rehabilitated soil + poultry manure + NPK (17-17-17)	Maize + Groundnut
10 - 12	Rehabilitated soil only (controls)	Maize + Groundnut

Growth conditions (watering, exposure, monitoring) were standardized across all substrates. Observations were focused on:

- germination rate,
- emergence delay (days),
- seedling vigor,
- average plant height and leaf coloration,
- behavioral differences between enriched substrates and the control.

## 4) Physical and Chemical Soil Analysis

The physical and chemical analyses of the rehabilitated soil were conducted to evaluate its quality and agronomic potential, with particular attention to its suitability for maize (*Zea mays* L.) and groundnut (*Arachis hypogaea* L.) cultivation. Two main objectives guided this assessment: first, to measure the impact of rehabilitation by comparing parameters obtained before and after the process; and second, to establish a soil amendment and fertilization plan adapted to the structure and composition of the soil, thereby improving agronomic performance.

Pre-rehabilitation data were collected three months prior to the intervention,

on the same site and by the same IRAG laboratory in Kindia, using identical protocols. These results were compared with post-rehabilitation analyses conducted after the fallow period. The analyses sought to determine whether the soil exhibited the physico-chemical and biological characteristics required to support sustainable crop production. This approach is particularly relevant in Guinea, where cropping practices must be adapted to local pedological conditions [14] [15].

According to FAO [10], tailoring agricultural practices to soil characteristics enhances fertility and sustainability, especially in tropical regions. Lal [16] emphasizes that soil management aligned with intrinsic properties is crucial for productivity and resilience to climate change. More recently, Roy [17] highlights the importance of adapting cropping practices to local pedological contexts to strengthen food security and farmer resilience in Guinea.

For these analyses, 1 kg was drawn from the homogeneous composite sample, placed in a labeled and dated plastic bag, and transported immediately to the IRAG laboratory. Subsamples (R1, R2, R3) were extracted and analyzed in triplicate to ensure reliability. The assessment of physico-chemical parameters is a critical step in characterizing fertility and understanding the interactions between substrates and crop growth. The methods applied are standardized and validated in international scientific literature [18] [19].

#### **5) Physical parameters**

Physical parameters were measured to characterize soil texture, density, and moisture content, following standardized protocols:

- Particle size distribution was determined using the Bouyoucos hydrometer method [20], supported by the USDA textural triangle for classification [21].
- True density ( $D_r$ ) was measured with a pycnometer [22].
- Bulk density ( $D_a$ ) was obtained using the cylinder method [23] providing an estimate of soil compaction.
- Moisture content was determined by oven drying at 105°C until constant weight [22].

#### **6) Chemical parameters**

Chemical properties were analyzed to evaluate fertility status and nutrient availability, using established laboratory methods:

- Soil acidity (pH) was measured by the potentiometric method [24].
- Organic matter content was quantified using the Anne method [25].
- Available phosphorus was extracted using the Bray II method [26], suitable for acidic soils.
- Total nitrogen was determined by the modified Kjeldahl method [27], involving acid digestion and distillation.
- Available potassium was assessed following FAO guidelines [26].
- Cation exchange capacity (CEC) and exchangeable bases were measured according to FAO [26], providing an overall assessment of soil chemical fertility.

### **2.3.3. Agricultural Production**

Maize production intercropped with groundnut was carried out during the 2020

rainy season, from June 7 to September 30. The varieties used were maize *Perta* and groundnut Local White. The total cultivated area was 2.275 ha, arranged in a 2:1 pattern (two rows of groundnut for one row of maize).

To ensure optimal plant density and compliance with agronomic standards, spacing and seed quantities were defined as follows:

- **Maize (Perta):** spacing of 0.80 m between rows and 0.40 m within rows; seed requirement: 34.00 kg.
- **Groundnut (Local White):** spacing of 0.40 m between rows and 0.15 m within rows; seed requirement: 136.00 kg.

The fertilizer application schedule was designed to optimize nutrient availability and crop growth, with inputs applied at specific stages of the production cycle:

- **Poultry manure:** incorporated into the soil two weeks before sowing (June 7, 2020), at a rate of 5 t/ha.
- **Superphosphate:** applied on the day of sowing (June 21, 2020), at a rate of 100 kg/ha.
- **NPK 17-17-17:** applied as top dressing at the 4 - 5 leaf stage of maize (July 12, 2020), at a rate of 150 kg/ha.

### 3. Results and Discussion

#### 3.1. Soil Management

The site, formerly exploited for bauxite and left degraded for fourteen years, suffered the consequences of prolonged topsoil storage. Exposed to climatic elements without protection, the soil underwent severe physical and chemical degradation. Contrary to technical recommendations that advise a maximum conservation period of two to three years, this extended delay led to structural loss and a decline in biological fertility.

Nevertheless, the applied amendments resulted in substantial improvements in soil properties: pH increased from 4.13 to 5.90 (+43%), correcting acidity and approaching the reference range (5.60 - 7.50); organic matter content rose nearly ninefold, from 0.58% to 5.50% (+848%), exceeding the standard range (2.50% - 5.00%); and cation exchange capacity (CEC) improved from 3.03 to 11.90 meq/100g (+293%), reflecting enhanced nutrient retention, although still below the optimal range (15 - 25 meq/100g), as shown in **Table 2**.

**Table 2.** Comparison of soil chemical parameters (*Data provided by the IRAG Soil Laboratory*).

Parameter	Pre-rehabilitation	Post-rehabilitation	Difference	Improvement rate (%)	Reference values
pH (water)	4.13	5.90	+1.77	43%	5.60 - 7.50
Organic matter (%)	0.58	5.50	+4.92	848%	2.50 - 5.00
CEC (meq/100g)	3.03	11.90	+8.87	293%	15.00 - 25.00

These improvements stem directly from the rehabilitation sequence—topsoil replacement, incorporation of lime, clay, and black soil, followed by a fifteen-month fallow period—confirming the effectiveness of an integrated approach. The correction of acidity, the remarkable increase in organic matter, and the significant rise in CEC demonstrate the capacity of targeted amendments to restore soil fertility even under conditions of extreme degradation.

The results are consistent with Lal [16], who emphasizes the importance of managing physico-chemical properties for productivity and climate resilience, as well as with FAO [10], and ANPROCA [28], which recommend the combined use of organic and mineral amendments. However, the CEC remains below optimal values, suggesting the need for further monitoring and possible additional inputs. The sustainability of the increase in organic matter must also be ensured through appropriate cropping practices, such as cover crops and residue management.

In summary, rehabilitation restored pedological conditions favorable to maize and groundnut cultivation, while underscoring the importance of integrated and contextualized management of post-mining soils.

### 3.2. Grass Cover Assessment

After fifteen months of fallow, the rehabilitated site exhibited significant grass cover, including creeping legumes (*Crotalaria*) and abundant grasses with well-developed root systems. The lush vegetation indicates renewed microbial activity, while root development demonstrates soil depth and fertility. The density and height of the grass cover attest to a satisfactory level of rehabilitation.

### 3.3. Maize-Groundnut Behavior Test

**Table 3** summarizes the comparative parameters observed in maize and groundnut seedlings under different substrate treatments. The variables measured include germination rate, emergence delay, vigor index, average height and leaf coloration.

At six weeks after sowing, enriched substrates showed clear superiority compared to the control (soil only), as indicated in the table below.

**Table 3.** Comparative parameters of seedlings (maize-groundnut) at 6 weeks (*Data provided by the IRAG Soil Laboratory*).

Substrate	Germination (%)	Emergence delay (days)	Vigor (index 1 - 5)	Average height (cm) Maize/Groundnut	Leaf coloration	Key observations
Soil + Manure	92	03-avr	4.2	28/14	Deep green	Rapid emergence, steady growth
Soil + NPK 17-17-17	89	03-avr	4.0	27/13	Bright green	Homogeneous emergence, fast growth
Soil + Manure + NPK	95	02-mars	4.6	30/15	Intense green	Accelerated emergence, highest vigor
Soil only (Control)	78	05-juin	3.2	22/11	Pale/yellowish	Delayed emergence, nutrient stress

Germination rates were high in fertilized treatments (92% - 95%), with reduced emergence delays (2 - 4 days) compared to 5 - 6 days for the control. Seedling vigor (index 4.0 - 4.6) and average height (27 - 30 cm for maize; 13 - 15 cm for groundnut) were also superior in enriched substrates, accompanied by intense green leaf coloration, indicating balanced nutrition.

The “Manure + NPK” treatment recorded the highest agronomic performance across all parameters: germination (95%), accelerated emergence (2 - 3 days), maximum vigor (4.6), uniform growth, and intense foliar coloration. This confirms the value of integrated fertilization—combining organic and mineral amendments—for optimizing early establishment and vegetative behavior of maize and groundnut.

Comparison of isolated inputs shows that manure alone promoted rapid emergence and steady growth, while NPK alone ensured homogeneous emergence and fast growth but slightly lower vigor. This suggests that organic inputs play a critical role in sustaining biological activity and enhancing nitrogen fixation in legumes.

In contrast, the control (soil only) exhibited delayed emergence (5 - 6 days), reduced germination (78%), low vigor (3.2), limited plant height (22 cm for maize; 11 cm for groundnut), and foliar chlorosis, reflecting nutrient stress.

Overall, this behavioral test demonstrates that integrated fertilization is the most effective strategy to optimize germination, accelerate emergence, promote uniform growth, and enhance the vigor and morphology of maize and groundnut seedlings. The findings are consistent with agronomic recommendations that emphasize rational fertilization practices—combining organic and mineral inputs—to restore soil fertility, improve resilience and performance in intercropping systems, and ensure balanced crop development in degraded environments.

### 3.4. Soil Agro-Pedological Parameters Assessment

Understanding soil texture and fertility is essential for guiding fertilization, irrigation, and erosion control strategies. It also informs assessments of water retention, porosity, permeability, and compaction sensitivity [29] [30]. In Guinea, where soils are highly variable and under increasing anthropogenic pressure, such analyses are critical for sustainable resource management [31] [32].

#### 3.4.1. Results and Interpretation of Soil Agro-Pedological Analysis

##### 1) Physical Parameters

**Table 1** summarizes the physical parameters measured across three soil samples from the cultivated plot. The low standard deviations confirm the statistical reliability of the measurements.

The average bulk density of the soil was 0.90 g/cm<sup>3</sup>, while the true particle density reached 2.40 g/cm<sup>3</sup>. These values correspond to a porosity of 63.40%, indicating a structure favorable to aeration and water retention. The mean moisture content was 11.00%, with a wilting point of 16.50% and a field capacity of 30.36%. Taken together, these parameters reveal a soil profile capable of sustaining crop

growth even under moderately stressful climatic conditions. Such values fall within the ranges generally reported for agricultural soils with good physical fertility and adequate water availability [11] [33]-[36].

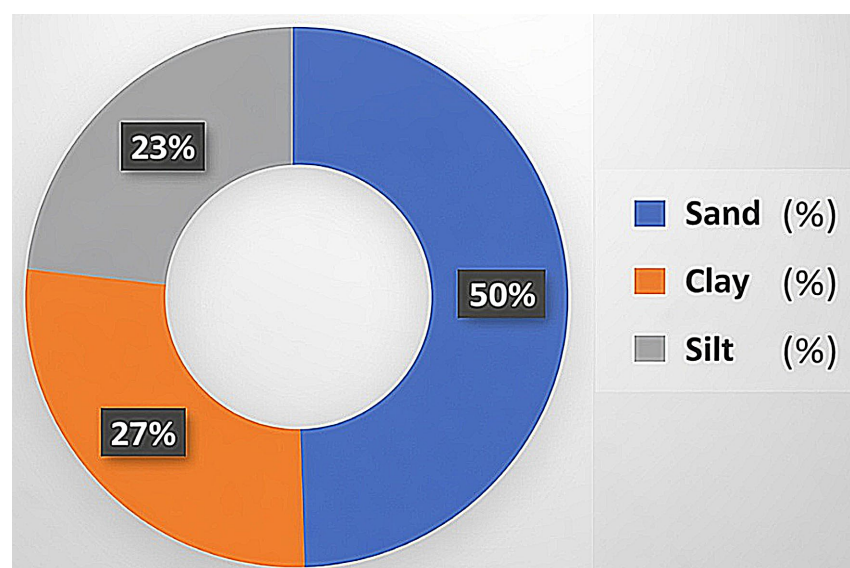
As shown in **Table 4**, **Figure 1** and **Figure 2** below, the soil composition averaged 49.68% sand, 27.04% clay, and 23.28% silt, corresponding to a sandy clay loam texture.

The USDA Textural Triangle was used to classify soils based on the relative proportions of sand, silt, and clay [37].

The sandy clay loam texture ensures good water-holding capacity, adequate aeration, and moderate chemical fertility—conditions well-suited for maize and groundnut cultivation [29].

**Table 4.** Summary of physical analysis results (R1 = Sample 1, R2 = Sample 2, R3 = Sample 3, Da = Bulk density, Dr = True density, FC = Field Capacity, WP = Wilting Point).

Parameters	R1	R2	R3	Average	Std. Dev.
Sand (%)	49.50	49.86	49.68	49.68	0.18
Clay (%)	26.84	27.24	27.04	27.04	0.20
Silt (%)	23.15	23.30	23.39	23.28	0.12
Texture	LAS	LAS	LAS	LAS	LAS
Bulk density (g/cm <sup>3</sup> )	0.91	0.87	0.92	0.90	0.03
True density (g/cm <sup>3</sup> )	2.29	2.42	2.49	2.40	0.10
Moisture content (%)	10.91	10.89	11.20	11.00	0.17
Porosity (%)	63.54	62.92	63.74	63.40	0.43
Field Capacity (%)	29.80	30.12	31.16	30.36	0.71
Wilting Point (%)	16.88	16.53	16.09	16.50	0.27



**Figure 1.** Soil particle size distribution.

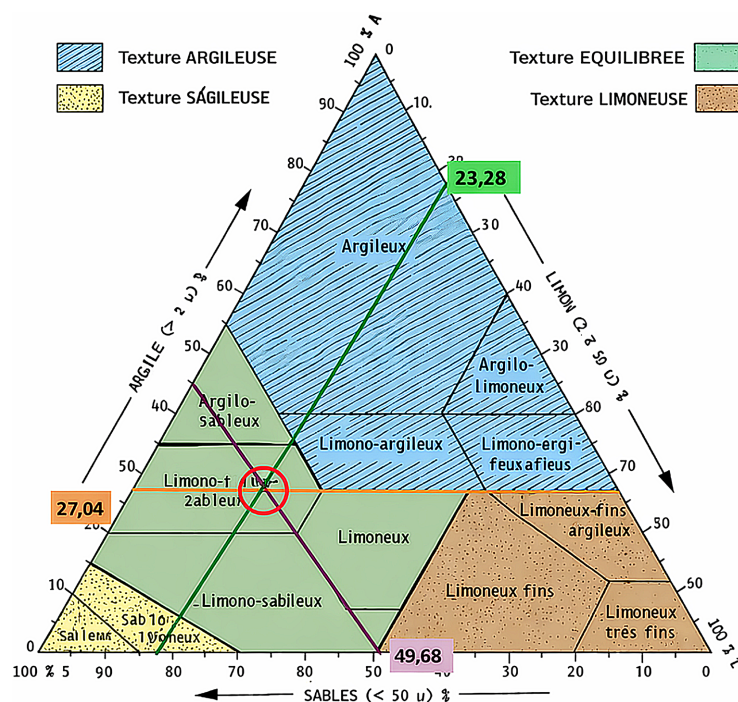


Figure 2. Soil textural triangle.

## 2) Chemical Soil Analysis

The results of the chemical analyses are presented in the following **Table 5** and **Table 6**.

**Table 5.** Results of soil chemical analysis (R1 = Sample 1, R2 = Sample 2, R3 = Sample 3).

Parameter	R1	R2	R3	Mean	Std. Dev.	Assessment	Reference*
pH (water)	5.5	6.0	6.2	5.90	0.36	Moderately acidic	5.60 - 7.50
Organic matter (%)	5.6	5.5	5.4	5.50	0.10	Rich	2.50 - 5.00
Total nitrogen (%)	0.27	0.28	0.27	0.27	0.005	Rich	0.10 - 0.15
C/N ratio	11.75	11.63	11.42	11.60	0.17	Satisfactory	12.00 - 18.00
Available nitrogen (mg/100g)	13.58	13.87	13.95	13.80	0.19	Very rich	2.00 - 4.00
Available phosphorus (mg/100g)	0.12	0.13	0.11	0.12	0.01	Very poor	3.00 - 15.00
Exchangeable potassium (mg/100g)	12.05	12.00	11.95	12.00	0.05	Medium	7.00 - 20.00
CEC (meq/100g)	12.03	11.70	11.97	11.90	0.18	Moderately low	15.00 - 25.00

\*Source: Soil Laboratory, IRAG.

**Table 6.** Soil nutrient reserves (kg/ha).

Parameter	R1	R2	R3	Mean	Std. Dev.
Nitrogen reserve (N)	248.2	250.0	247.0	248.40	1.51
Phosphorus reserve ( $\text{P}_2\text{O}_5$ )	2.15	1.98	2.35	2.16	0.19
Potassium reserve ( $\text{K}_2\text{O}$ )	216.0	216.0	216.0	216.00	0.00

The tables show:

- **Soil pH:** The soil is moderately acidic (5.90), which may limit phosphorus availability. Liming is recommended to reach an optimal pH of around 6.2, favorable for nitrogen fixation and phosphorus uptake.
- **Organic matter (OM):** The organic matter content is high (5.5%), above standard values. This richness supports soil structure, microbial activity, and nutrient retention. Regular applications of compost (8 - 10 t/ha) are advised to maintain this level.
- **Total and available nitrogen:** Nitrogen levels are very satisfactory (0.27% and 13.8 mg/100g), with a reserve of 248.4 kg/ha. The C/N ratio of 11.6 indicates good mineralization. However, supplementary inputs remain necessary for maize, a nitrogen-demanding crop.
- **Available phosphorus (P<sub>2</sub>O<sub>5</sub>):** The phosphorus content is very low (0.12 mg/100g), well below threshold values. An application of 40 - 60 kg/ha of triple superphosphate is essential to improve maize rooting and peanut nodulation.
- **Exchangeable potassium (K<sub>2</sub>O):** The level is medium (12 mg/100g). An application of 60 - 80 kg/ha of potassium sulfate is recommended to strengthen drought tolerance and grain quality.
- **CEC (Cation Exchange Capacity):** The measured value (11.9 meq/100g) is moderately low, limiting nutrient retention. Regular organic inputs are required to improve the soil's buffering capacity and ensure better nutrient availability.

### 3.4.2. Amendment Plan

In order to address the constraints identified during the physico-chemical analyses of the soil, an amendment plan was designed and implemented. The results obtained are presented in **Table 7** below, followed by a critical discussion of their agronomic and economic relevance.

**Table 7.** Amendment plan for the maize-groundnut association.

Amendment	Applied dose	Date/Time of application	Agronomic justification
Poultry manure compost	4 t/ha	June 7, 2020 (two weeks before sowing)	Improves organic matter, stimulates microbial activity, and strengthens CEC
Triple superphosphate (P <sub>2</sub> O <sub>5</sub> )	70 kg/ha	June 21, 2020 (at sowing)	Corrects severe phosphorus deficiency, promotes groundnut nodulation and maize rooting
NPK 17-17-17	150 kg/ha (single dose)	July 12, 2020 (at the 4 - 5 leaf stage of maize)	Provides N, P, and K in a simple and cost-effective manner at the critical crop establishment stage

The initial analyses revealed a soil rich in organic matter and nitrogen, but severely deficient in phosphorus and with a relatively low cation exchange capacity. The amendment plan directly addresses these constraints.

The application of poultry manure compost two weeks before sowing promoted progressive mineralization and improved soil structure, while enhancing nutrient retention capacity. Triple superphosphate, applied separately at sowing, effectively corrected the phosphorus deficiency and stimulated groundnut nodulation

as well as maize rooting. This temporal dissociation between organic and mineral inputs is consistent with scientific recommendations, as it optimizes nutrient availability and prevents negative interactions.

Regarding NPK 17-17-17, a single application on July 12, 2020 (at the 4 - 5 leaf stage of maize) represents an economically viable and logistically simplified option for farmers. Although splitting the dose into two applications could improve agronomic efficiency, it would generate additional labor costs and management complexity. In smallholder contexts, the single application remains a recommended practice, as it ensures immediate nutrient availability at the critical crop establishment stage while reducing economic constraints.

Thus, the adopted amendment plan illustrates a rational fertilization strategy, integrating both organic and mineral inputs, and adapted to Guinean production conditions. It contributes to restoring soil fertility, improving the productivity of the maize-groundnut system, and strengthening the sustainability of agricultural practices. These results confirm that integrating analytical data with agronomic and economic recommendations constitutes an effective approach for sustainable soil management.

### 3.5. Agricultural Production

The rehabilitation of degraded soils from a former bauxite quarry was tested through maize-groundnut intercropping, a practice recognized for its agronomic and ecological benefits. Maize, with its deep root system, improves soil structure by promoting particle aggregation, thereby increasing porosity, facilitating water infiltration, and reducing compaction [38]. Its dense vegetative cover protects the soil from raindrop impact, limits runoff, and reduces water erosion. Groundnuts, as nitrogen-fixing legumes, enrich the soil with nutrients, stimulate microbial activity, and enhance biological fertility [39].

Nitrogen plays a central role in activating soil microflora. By supporting the growth of decomposer bacteria and fungi, it accelerates the transformation of organic matter into humus and releases plant-available nutrients. This process improves fertility by strengthening nutrient retention capacity, increasing cation exchange capacity (CEC), and promoting the formation of stable aggregates. Nitrogen fixed by groundnuts thus contributes to reactivating nutrient cycles and restoring soil ecological functions [10] [16] [39].

Comparative analyses of tropical cropping systems show that maize-legume intercropping generates yields 15% - 20% higher than monocultures, due to functional complementarity in nutrient absorption, denser vegetative cover, and reduced nutrient losses through leaching [40]. These findings confirm the effectiveness of the implemented organo-mineral amendment plan, both agronomically and economically, in line with the principles of sustainable fertility, agroecological resilience, and food sovereignty, consistent with FAO recommendations [10] and the foundations of tropical agroecology [16] [38].

From an agroecological perspective, maize-groundnut intercropping contrib-

utes to:

- restoring soil structure through aggregate stabilization and improved porosity;
- carbon sequestration via root biomass accumulation and stimulation of organic matter;
- regulation of the water cycle through improved infiltration and retention;
- increased resilience to climatic stresses, including droughts and extreme temperatures;
- reactivation of microbial biodiversity, essential for nutrient mineralization and soil health [39] [10].

The study recorded yields slightly below regional theoretical averages, with respective gaps of 13.50% for maize and 17.33% for groundnuts (**Table 8**). Despite these differences, the outcomes remain significant, as they validate the initial hypothesis: an abandoned bauxite quarry in Sangarédi, left unused for 14 years, can be rehabilitated and valorized for maize-groundnut cultivation.

**Table 8.** Maize and groundnut production results (\*Theoretical averages provided by the prefectural branch of ANPROCA, Boké).

Crop	Area (ha)	Quantity Produced (T)	Actual Yield (T/ha)	Theoretical Yield (T/ha)*	Yield Gap (%)	Post-harvest Loss (T)	Quantity Consumed (T)	Quantity Sold (T)
Maize	2.275	7.88	3.46	4.00	-13.50	0.12	1.20	6.56
Groundnut		5.64	2.48	3.00	-17.33	0.10	0.80	4.74

Beyond agronomic and ecological limitations, social constraints also influenced production outcomes. The sudden demobilization of certain group members, linked to land tenure tensions and customary claims, disrupted the organization of collective work. Interviews with local authorities, village elders, and technical agents revealed that some former landowners insisted that all exploitation should remain subject to their authority, demanding financial compensation contrary to legal frameworks.

This situation led to family conflicts, reduced participation of women—the main actors in the groups—and a decline in available labor for maintenance and field guarding. Social tensions had direct repercussions on production: the cropping calendar was not respected, pest attacks (squirrels, monkeys) increased, and yields were negatively affected. The intervention of administrative and religious authorities at the communal and prefectural levels helped ease tensions and clarify land management rules.

In sum, these factors highlight the importance of clear land governance, prior community mobilization, and participatory planning, as well as the rigorous implementation of technical steps, including landform reconstruction, water management, and the valorization of degraded soils [41] [42].

## 5. Conclusion

This study demonstrates the technical, social, and environmental feasibility of re-

habilitating a former bauxite quarry into agricultural land, with tangible benefits for surrounding communities. Agro-pedological and agronomic results confirm that, despite physical constraints (compaction, low cation exchange capacity) and chemical limitations (severe phosphorus deficiency), soil fertility can be restored through an integrated approach. The performances obtained—7.88 tons of maize, of which 6.56 tons were marketed, 1.20 tons consumed locally, and only 0.12 tons lost—reflect an encouraging dynamic of progress, even though they remain below regional theoretical averages (13.50% lower for maize and 17.33% for groundnut). Beyond productive outcomes, this experience highlights the potential of agroecology to restore soil ecological functions, foster biodiversity regeneration, stabilize degraded land, and ensure viable food production in mining zones such as Boké.

## 6. Recommendations and Perspectives

To consolidate these achievements and ensure the sustainability of rehabilitation projects, several orientations are proposed:

- **Technical and environmental reinforcement:** improve management of the stripped topsoil, develop integrated pest management strategies, optimize physical site rehabilitation, and incorporate environmental monitoring (biodiversity, water quality, soil stability).
- **Agronomic optimization:** continue the integrated fertilization approach (manure + NPK + superphosphate), which addresses specific deficiencies while valorizing low-cost local inputs.
- **Economic dimension:** promote “economic fertility” by combining agronomic productivity, cost control, and sustainability, thereby contributing to food security and nutritional sovereignty.
- **Scientific deepening:** conduct complementary research to adapt this model to other mining regions in Guinea, with long-term monitoring of soil fertility, yields, and environmental indicators.
- **Social mobilization and governance:**
  - Involve local technical services from the outset to ensure scientific and practical support.
  - Integrate local practices to strengthen community ownership.
  - Engage administrative and religious authorities early in the design phase, so they can play a role in conflict prevention and management.
  - Ensure information sharing so that all stakeholders have equal knowledge of the project.
  - Disseminate the legal provisions governing rehabilitation in Guinea to reinforce transparency and legitimacy.

## Conflicts of Interest

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

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