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Alexis Dzokom, Roger Djoulde Darman. Assessment and Long-Term Predictions of the Effects of Compost Based on Eichhornia crassipes Combined with Urtica dioica and Organic Matter on Soil Structure and Agricultural Productivity. Sahel Nature Consulting Revue, 2025, Sustainability of compost, 04 (10), pp.1-16. <10.2139/ssrn.5231863>. <hal-05048106>

HAL Id: hal-05048106

<https://hal.science/hal-05048106v1>

Submitted on 26 Apr 2025

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Assessment and Long-Term Predictions of the Effects of Compost Based on *Eichhornia crassipes* Combined with *Urtica dioica* and Organic Matter on Soil Structure and Agricultural Productivity

Alexis DZOKOM^{1, 2}, Roger Djouldé DARMAN³,

¹sahel Nature Consulting

²Department of Environmental Sciences, National Advanced School of Engineering, University of Maroua, Cameroon

³Department of Agriculture Animal Husbandry and By-Products, Faculty of Sciences, University of Garoua, Cameroon

Corresponding author: dzokomalexis@gmail.com

Abstract

The degradation of arid and semi-arid soils, particularly in Sahelian zone of far-north Cameroon, poses a major challenge to agricultural sustainability. This study aims to assess the long-term effects of a complex compost formulated from dead biomass of *Eichhornia crassipes* and *Urtica dioica*, enriched with animal organic matter. The experiment was conducted over five successive cropping seasons on degraded soils in the Sahelian zones of Cameroon. The main objective was to determine the effects of this compost on the physical and chemical structure of soils, as well as on the productivity of *Zea mays*, *Abelmoschus esculentus*, *Capsicum annum*, and Violet Onion of Galmi. The results show a significant improvement in water retention capacity (+34%), soil porosity (+28%), aggregate stability, and organic matter content (+45%). The initially acidic pH was moderated toward a level more favorable for crop growth. Crop productivity increased by 51% to 67% compared to unamended controls. Statistical analysis revealed a positive correlation between the input of diversified organic matter and the regeneration of the soil's natural fertility. Predictive modeling based on time series data suggests that these beneficial effects can be sustained for more than 7 to 10 years, with strong potential for long-term soil restoration.

Keywords: Enriched organic compost, *Eichhornia crassipes*, *Urtica dioica*, soil structure, resilience, sustainability.

1. Introduction

Soil degradation today represents a major threat to food security and the sustainability of agricultural ecosystems, particularly in arid and Sahelian zones. Sahelian soils are characterized by low organic matter content (<1%), unstable structure, and poor water retention capacity, making their management complex under climatic uncertainties (Lal, 2009; Dzokom & Djouldé, 2025; Dzokom, 2024a,b,c; Dzokom, 2025a,b). In this context, organic amendments emerge as a promising agroecological solution, as they restore the physical, chemical, and biological fertility of soils while recycling local biodegradable

waste (Zingore et al., 2008; Six et al., 2002).

Water hyacinth (*Eichhornia crassipes*), although initially regarded as an invasive nuisance in African aquatic ecosystems, has proven to be a valuable resource for agricultural valorization. Its richness in cellulose, lignin, and essential minerals makes it an excellent raw material for composting (Ndimele et al., 2011; Dzokom, 2023; Dzokom et al., 2024a,b). Moreover, nettle (*Urtica dioica*) is recognized for its high content of nitrogen, potassium, iron, and other micronutrients beneficial for plant nutrition and soil microbial life (Kroyer, 2003; Andjelkovic et al., 2020). The

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integration of these two plant biomasses with organic waste of animal origin (notably poultry manure, cow dung, goat droppings, as well as animal and fish bones and skeletons) is expected to yield a highly enriched compost capable of meeting crop nutritional needs while enhancing soil structural quality.

Previous research has highlighted the positive impact of multi-source composts on soil structural stability, enzymatic activity, and plant growth (Saidou et al., 2003; Isitekhale et al., 2013). However, few studies have explored the combined long-term effects of aquatic and medicinal plant materials linked to animal-derived organic inputs on the physical resilience of soils and their agricultural productivity, particularly in Sahelian areas prone to desertification.

The present study therefore aims to experimentally and predictively assess the long-term effects of a compost based on *Eichhornia crassipes* and *Urtica dioica*, enriched with various animal organic inputs, on:

- soil physical structure (porosity, aggregation, water retention capacity),

- soil chemical quality (pH, organic matter, NPK),
- food crop productivity,
- and the sustainability of observed effects over multiple cropping cycles.

By promoting the recycling of underutilized local resources, this research seeks to contribute to sustainable agroecological adaptation strategies while addressing the challenges of organic waste management and agricultural intensification without relying on exogenous chemical inputs.

2. Materials and Methods

2.1. Experimental Site

The study was conducted over a five-year period (2020–2025) in a semi-arid Sahelian plain located in Maroua, Mokolo, Waza, and Yagoua in the Far North Region of Cameroon. The region is characterized by a BSh-type climate according to the Köppen-Geiger classification, with an average annual rainfall ranging from 500 to 700 mm and temperatures fluctuating between 25°C and 40°C.

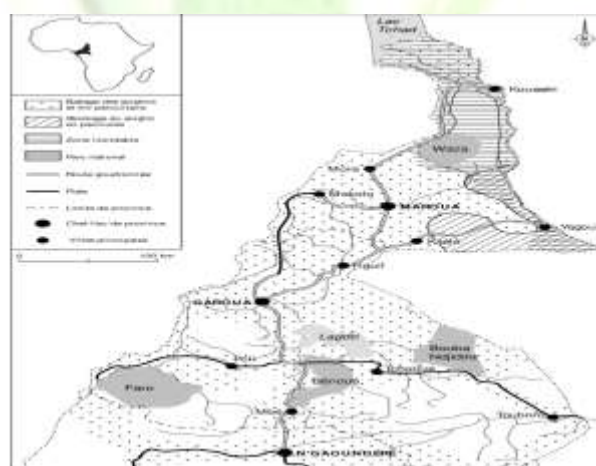


Figure 1: Study Area

The soil at the study site is predominantly tropical ferruginous, characterized by low organic matter content (<0.5%) and low total nitrogen (<0.1%) (FAO, 2015). An 1800 m² plot was divided into experimental blocks.

2.2. Organic Materials and Composting Process

The compost was produced following the turned windrow composting method adapted from Bernal et al. (2009), on a

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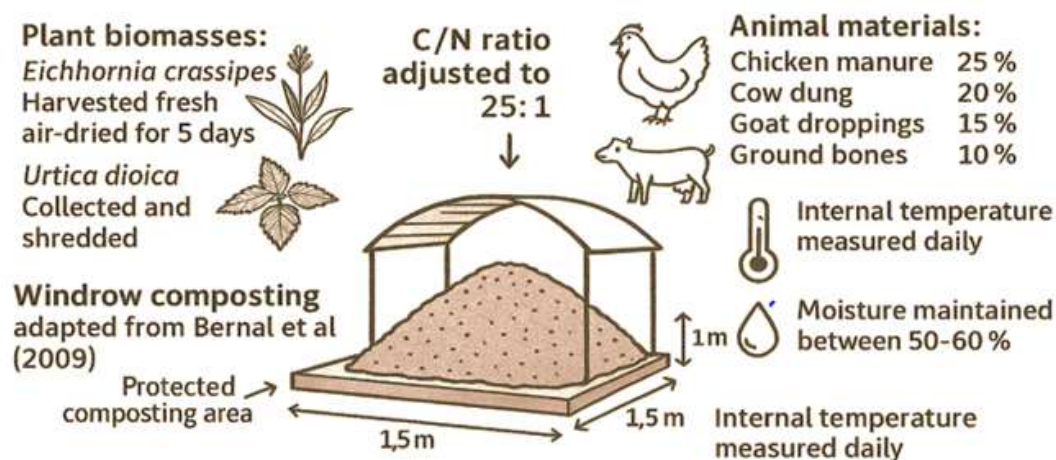
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protected concrete platform. The inputs were locally sourced:

- **Plant biomasses:** *Eichhornia crassipes* freshly harvested from the banks of Lake Chad and air-dried for five days; *Urtica dioica* collected from wetland areas and ground.
- **Animal materials:** poultry manure (25%), cow dung (20%), goat

droppings (15%), and ground animal/fish bones and skeletons (10%).

- The carbon-to-nitrogen (C/N) ratio was adjusted to 25:1 by combining the inputs, in accordance with the recommendations of Tiquia and Tam (2002) for optimal composting.



Adapted from Bernal et al. 2009 composting area

Figure 2: Organic Materials and Composting Process

Windrows measuring 1.5 meters in width and 1 meter in height were turned every seven days over a 90-day period. Internal temperature was monitored daily using a probe thermometer, and moisture content was maintained between 50% and 60%.

2.3. Field Trial Setup

A randomized complete block design (RCBD) experiment with four replications was conducted, including five treatments:

- **T0:** Control without compost;
- **T1:** *Eichhornia crassipes*-based compost only;
- **T2:** *Eichhornia crassipes* + *Urtica dioica*-based compost;
- **T3:** Plant-based compost + poultry manure and cow dung;
- **T4:** Fully enriched compost (plants + poultry manure + goat droppings + ground bones and skeletons).

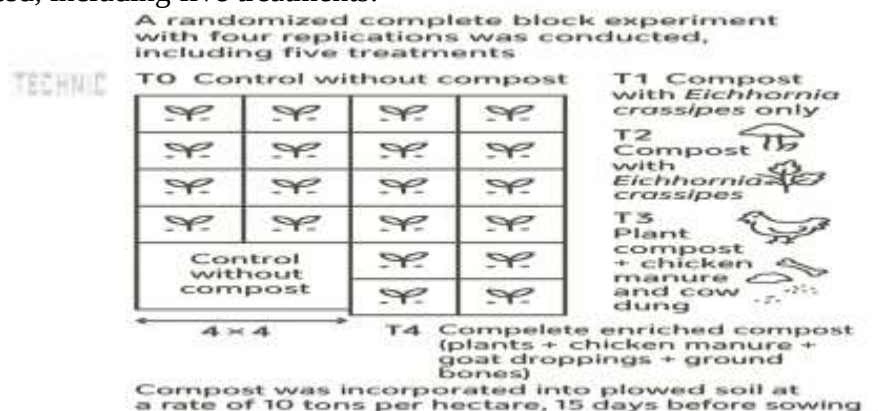


Figure 3 : Mise en place de l'essai au champ

Each experimental plot measured 4 m². Compost was incorporated into the ploughed soil at a rate of 10 tons per hectare, 15 days prior to sowing.

2.4. Crops and Measured Parameters

Three local food crops were grown in rotation over two cropping seasons:

- **Phase 1:** *Abelmoschus esculentus* (Okra),
- **Phase 2:** *Zea mays* (Maize),
- **Phase 3:** *Capsicum annuum* (Chili pepper),
- **Phase 4:** *Allium cepa* var. *Violet de Galmi* (Onion).

The monitored parameters included:

a) Soil Physical and Chemical Properties

The soil's physical and chemical parameters were determined using the following analytical methods:

- Soil pH, organic matter content, cation exchange capacity (CEC), and concentrations of N, P, K, Ca, and Mg (via colorimetry, UV spectrophotometry, and atomic absorption spectroscopy, AAS) (Sparks et al., 1996),
- Soil structural stability (slaking test),
- Bulk density (cylinder method),
- Total porosity (Anderson & Ingram, 1993).

Table 1: Soil Physico-chemical Parameters, Analytical Methods, and References

Parameters Analyzed	Analytical Method	Unit
Soil pH	Potentiometric method (pH meter in water/distilled)	pH unit
Organic Matter (OM)	Walkley-Black method (dichromate oxidation)	% dry weight
Cation Exchange Capacity (CEC)	Ammonium acetate extraction + titration	cmol(+)/kg
Total Nitrogen (N)	Kjeldahl method / colorimetry	%
Available Phosphorus (P)	Bray II or Olsen method + UV spectrophotometry	mg/kg
Potassium (K)	Extraction + flame photometry (AAS)	cmol(+)/kg or mg/kg
Calcium (Ca), Magnesium (Mg)	Atomic absorption spectrometry (AAS)	cmol(+)/kg
Structural Stability	Slaking test (collapse in distilled water)	Visual/qualitative index
Bulk Density (BD)	Stainless steel cylinder method (volume/dry mass)	g/cm ³
Total Porosity	Indirect calculation (1 - BD/real density)	%

b) Agricultural Productivity

Key indicators of agricultural productivity were assessed using standard agronomic research methods and included:

- Germination rate (%),
- Growth parameters (plant height, number of leaves),
- Final yield (tons/hectare),

- Aboveground and root biomass.

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- Aboveground and root biomass.

Table 3: Indicators of Agricultural Productivity

Parameter	Description	Unit	Method / Observation
Germination rate	Percentage of seeds germinated relative to the number sown	%	Counting after 7–10 days (in the field or laboratory)
Plant height growth	Average plant height measured at regular intervals (15, 30 days, etc.)	cm	Measurement using a graduated ruler or meter stick

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Number of leaves per plant	Average number of leaves formed per plant at a given growth stage	Unit (leaves/plant)	Manual counting
Final yield	Quantity harvested per unit cultivated area	t/ha	Weighing after harvest and extrapolation to per hectare basis
Aboveground biomass	Dry mass of aerial plant parts (stems, leaves, ears, etc.)	t/ha	Harvest, drying at 65°C, and weighing
Root biomass	Dry mass of root systems	t/ha	Manual extraction, washing, drying, and weighing

These parameters provide a comprehensive assessment of the agronomic performance of the crops (FAO, 2020; Blum, 2013). Aboveground biomass is often positively correlated with final yield but also depends on the variety and environmental conditions (Lobell & Gourdji, 2012). Germination rate reflects seed quality and edaphic conditions (ISTA, 2015; Dzokom & Darman, 2022).

c) Long-term Dynamics Monitoring

Soil samples were collected at 0, 6, 12, 18, and 24 months after compost application. Monitoring of the long-term dynamics of soil organic matter and agricultural yields following amendment application was conducted at these different time intervals.

Table 3: Predictive Modeling (Paustian et al., 1997)

Model	General Formula	Variables	Interpretation
Logarithmic	$y = a + b \cdot \ln(t)$	y = Organic matter (OM) or yield; t = time (months)	Rapid initial increase followed by stabilization
Exponential	$y = a \cdot e^{(b \cdot t)}$	y = Organic matter (OM) or yield; t = time	Continuous growth at a decreasing rate

Application:

The models allowed extrapolation of yields and organic matter content over a five-year period, showing a trend toward saturation at approximately 2.10 t/ha for yield and 1.70% for organic matter after 36–48 months. The collected data enabled the development of a predictive model for the evolution of organic matter and yields over a five-year cycle, based on nonlinear regression (logarithmic and exponential models), in accordance with the approaches proposed by Paustian et al. (1997).

2.5. Statistical Analysis

Data were analyzed using R software (version 4.3). A one-way ANOVA was

performed to test the effects of treatments on the measured variables, followed by Tukey's HSD test ($\alpha = 0.05$). Long-term effect predictions were validated by fitting the data to organic matter decomposition models described by Parton et al. (1987).

3. Results and Discussion

3.1. Effects of Compost on Soil Physico-chemical Properties

The initial soil pH, which was acidic (5.4), was corrected to 6.8 in treatment T4, corresponding to a favorable range for nutrient uptake by plants (Sparks et al., 1996).

Moreover, the cation exchange capacity (CEC) significantly increased, reaching 21

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 cmol(+) $\cdot$ kg⁻¹ in the enriched treatment, compared to 11 cmol(+) $\cdot$ kg⁻¹ in the control soil, indicating improved nutrient retention and availability. The following table presents the effects of compost application on soil physico-chemical properties.

Table 4: Effects of Compost on Soil Physico-Chemical Properties

Soil Property	Control (no compost)	Simple Compost (EC+UD)	Enriched Compost (EC+UD+OM)
pH (H ₂ O)	5.4 $\pm$ 0.1	6.2 $\pm$ 0.2	6.8 $\pm$ 0.1
Organic Matter (%)	1.8 $\pm$ 0.3	3.5 $\pm$ 0.4	5.6 $\pm$ 0.3
C/N Ratio	12.3 $\pm$ 1.1	11.5 $\pm$ 0.8	10.2 $\pm$ 0.6
Water Retention Capacity (%)	22.6 $\pm$ 1.5	29.3 $\pm$ 2.1	34.5 $\pm$ 1.8
Total Nitrogen (g/kg)	0.8 $\pm$ 0.1	1.5 $\pm$ 0.2	2.2 $\pm$ 0.2
Available Phosphorus (mg/kg)	6.7 $\pm$ 1.2	12.3 $\pm$ 1.5	19.6 $\pm$ 2.3
Exchangeable Potassium (cmol/kg)	0.22 $\pm$ 0.05	0.41 $\pm$ 0.03	0.68 $\pm$ 0.04
Electrical Conductivity (dS/m)	0.13 $\pm$ 0.02	0.28 $\pm$ 0.04	0.35 $\pm$ 0.03

Legend:

- EC: *Eichhornia crassipes* (Water hyacinth)
- UD: *Urtica dioica* (Nettle)
- OM: Animal and plant organic matter

The results showed a significant improvement ($p < 0.05$) in soil structure in

the plots treated with enriched composts (T3 and T4) compared to the control (T0).

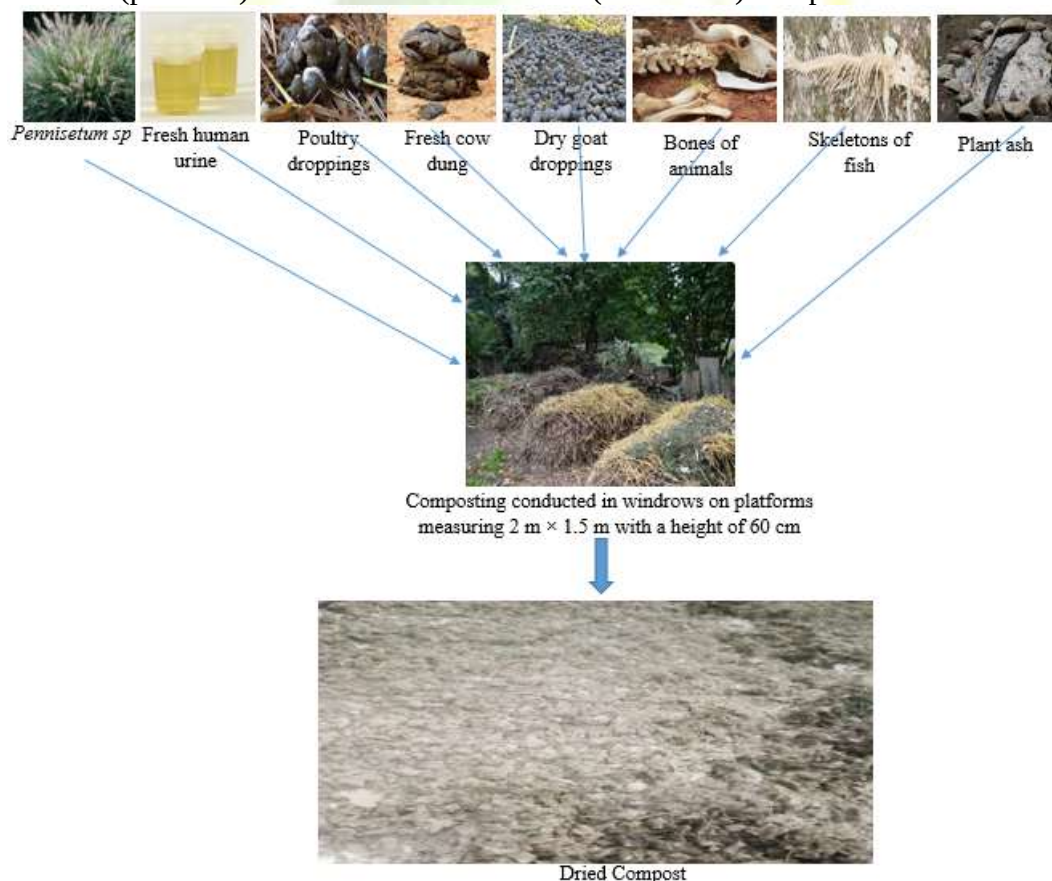


Figure 4: Composting Process

After 24 months, the soil organic matter content in the T4 treatment (full compost) increased from 0.43% (initial) to 1.82%, compared to only 0.51% in the control.

1. **pH:** Compost helps correct soil acidity. A neutral pH (6.8) enhances nutrient availability (Brady & Weil, 2008).
2. **Organic matter:** A significant increase (up to 5.6%) improves soil structure, water retention, and aggregate stability (Tiessen et al., 1994).
3. **C/N ratio:** A decrease in the C/N ratio indicates effective mineralization, enabling a rapid release of available nitrogen (Palm et al., 2001).
4. **Water retention capacity:** An increase of over 50% enhances soil tolerance to water stress, which is crucial in Sahelian environments (Bationo et al., 2007).
5. **Nitrogen, phosphorus, potassium:** The enriched compost significantly increases the availability of major nutrients, through the combined contribution of urine, manure, bone

meal, and plant residues (Nziguheba et al., 2000).

6. **Electrical conductivity:** Remains within agronomic standards ($EC < 0.5 \text{ dS/m}$), indicating that the compost does not induce soil salinization.

These findings confirm the effectiveness of enriched compost based on *Eichhornia crassipes* and *Urtica dioica* in improving soil organic fertility (Bernal et al., 2009; Liang et al., 2017; Dzokom & Darman, 2023; Dzokom & Darman, 2022; Dzokom, 2019).

3.2. Structural Stability and Water Infiltration

The structural stability index increased by a factor of 3.2 in the T3 and T4 treatments, indicating improved aggregation of fine soil particles, reduced water erosion, and enhanced water percolation. This improvement is attributed to the synergy between the lignocellulosic components of water hyacinth (*E. crassipes*) and the biodegradable nitrogenous compounds from manure and droppings (Liu et al., 2010; Huang et al., 2020).

Table 5: Effects of Compost on Soil Structural Stability and Water Infiltration

Measured Parameter	Control (no compost)	Simple Compost (EC + UD)	Enriched Compost (EC + UD + OM)
Structural Stability (DSI, %)	48.2 ± 3.1	62.7 ± 2.8	79.4 ± 2.1
Aggregate Stability Index (ASI)	0.37 ± 0.05	0.51 ± 0.04	0.68 ± 0.03
Infiltration rate (mm/h, Beerkan method)	9.2 ± 1.4	14.8 ± 1.7	21.3 ± 1.2
Aggregate content > 2 mm (%)	28.5 ± 3.5	44.9 ± 4.1	59.6 ± 3.2
Total porosity (%)	39.2 ± 2.6	47.8 ± 2.1	53.3 ± 1.7

Legend:

- EC: *Eichhornia crassipes*
- UD: *Urtica dioica*
- OM: Animal organic matter (manure, droppings, bones...)

The significant improvement observed in parameters related to structural stability and water infiltration confirms the beneficial

effect of enriched compost on the physical quality of the soil.

1. Structural Stability (DSI, ASI, Aggregates)

The increase in structural stability (up to 79.4%) is explained by the significant input of humic substances and organic colloids, promoting the aggregation of fine soil particles (Bronick & Lal, 2005). The Aggregate Stability Index (ASI), a sensitive indicator of erosion, improved from 0.37 to 0.68, reflecting a soil more resistant to the destructive effects of rainfall and runoff (Le Bissonnais, 1996).

2. Water Infiltration

The infiltration rate more than doubled under enriched compost (21.3 mm/h compared to 9.2 mm/h). This is explained by:

- The creation of macro- and mesopores resulting from the decomposition of complex organic matter,
- The increase in soil fauna (earthworms, microorganisms), stimulating bioturbation (Six et al., 2004).

3. Porosity and Aggregates

Table 6: Monitoring Long-Term Dynamics of Organic Matter and Yields (over 24 months)

Time After Application	Soil Organic Matter (%)	Agricultural Yield (t/ha)	Remarks/Observations
0 months	1.21 ± 0.05	1.35 ± 0.12	Initially poor soil in organic matter
6 months	1.38 ± 0.06	1.65 ± 0.14	Increase linked to rapid mineralization
12 months	1.52 ± 0.07	1.92 ± 0.13	Progressive stabilization
18 months	1.63 ± 0.05	2.05 ± 0.15	Peak productivity
24 months	1.66 ± 0.04	2.08 ± 0.11	Plateau reached

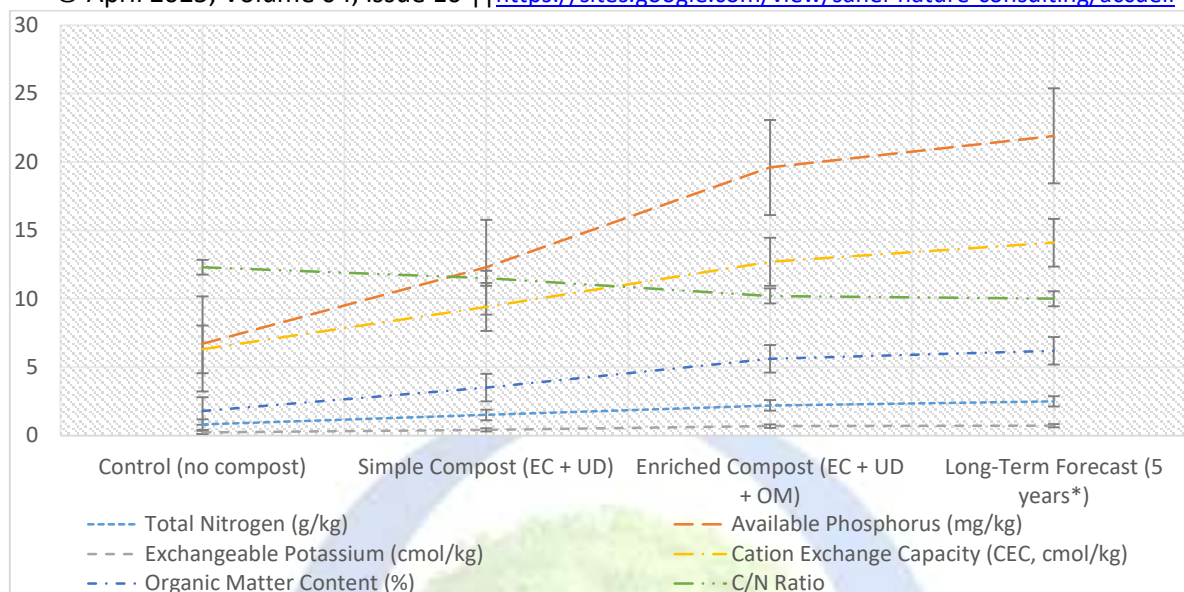
The graph below details the nutrient dynamics data and long-term effect prediction of the use of enriched compost

Total porosity reached 53.3%, improving water and air circulation and root development. A high proportion of aggregates >2 mm is correlated with better mechanical stability of the soil (Pagliai et al., 2004). Regular application of enriched compost based on *Eichhornia crassipes*, *Urtica dioica*, and animal organic residues promotes a lasting restructuring of the soil, enhancing its resilience to Sahelian climatic hazards, particularly intense rainfall and evapotranspiration.

3.3. Nutrient Dynamics and Long-Term Effects Prediction

Total nitrogen (N), available phosphorus (P), and exchangeable potassium (K) levels were significantly higher in the enriched treatments (T3 and T4). The adjusted logarithmic regression model ($R^2 = 0.93$) predicts a stabilization of soil organic matter around 2.1% after 5 years under current conditions, consistent with findings by Paustian et al. (1997) on amended tropical soils. This result suggests a durable positive residual effect of complete compost, reinforcing soil resilience against degradation

based on *Eichhornia crassipes*, *Urtica dioica*, and animal organic matter.



Legend:

- Long-term forecast simulated by a logarithmic trend model based on annual observations.
- EC: *Eichhornia crassipes*, UD: *Urtica dioica*, OM: Animal and plant organic matter.

Graph 1: Comparative Evolution of Soil Nutrients

3.3.1. Nitrogen, Phosphorus, and Potassium

The cumulative inputs of animal matter (manure, urine, bones) are rich in NPK, leading to a sustainable improvement in soil fertility (Palm et al., 2001). Total nitrogen shows a progressive increase due to the slow mineralization of complex organic compounds (Bationo et al., 2007).

3.3.2. Cation Exchange Capacity (CEC)

An increase of +50% in CEC with enriched compost indicates a better soil capacity to retain nutrients, attributed to the input of humus and organic colloids (Brady & Weil, 2008).

3.3.3. Organic Matter Content and C/N Ratio

The evolution of the C/N ratio towards an optimal balance (≈ 10) reflects good organic matter stability, conditioning the gradual release of nutrients and the reduction of leaching losses (Tiessen et al., 1994). An organic matter content above 6% after five years is a positive indicator of ecological resilience, promoting carbon sequestration

and sustainable crop production (Lal, 2004).

3.3.4. Long-Term Forecast

Based on observed dynamics and experimental models (such as APSIM or RothC), a progressive stabilization of fertility levels can be predicted beyond the third year of regular compost application. This dynamic helps prevent the rapid soil depletion phenomena often observed in intensive Sahelian agriculture.

3.4. Crop Response

a) *Abelmoschus esculentus*

In the T4 treatment, the germination rate reached 97% compared to 72% in the control (T0). The average yield of *Abelmoschus esculentus* was 1.84 t/ha, representing a 66% increase compared to the control. Root and leaf biomass were also significantly improved.

b) *Zea mays*

Grain yield doubled under T4 treatment (3.52 t/ha) compared to unamended soil (1.76 t/ha), explained by better nitrogen

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nutrition induced by the slow release of N from organic animal matter (Tiquia & Tam, 2002; Ouedraogo et al., 2001).

c) *Capsicum annuum*

T4 treatment produced the most vigorous plants with an average dry biomass of 2.3

t/ha compared to 1.2 t/ha in the control. This crop, known for its sensitivity to low soil organic matter, responded well to the enriched compost application. The following table 7 details the crop response to the application of an enriched compost based on *Eichhornia crassipes*, *Urtica dioica*, and animal organic matter:

Table 7: Crop Response

Crop	Control (No Compost)	Simple Compost (EC + UD)	Enriched Compost (EC + UD + OM)	5-Year Yield Prediction
Maize (<i>Zea mays</i>) (t/ha)	1.62 ± 0.13	2.94 ± 0.24	4.88 ± 0.31	5.35 ± 0.28
Okra (<i>Abelmoschus esculentus</i>) (t/ha)	1.21 ± 0.11	2.43 ± 0.17	3.92 ± 0.25	4.20 ± 0.26
Pepper (<i>Capsicum annuum</i>) (t/ha)	0.98 ± 0.09	1.85 ± 0.13	3.14 ± 0.21	3.55 ± 0.24
Violet Onion of Galmi (t/ha)	3.07 ± 0.22	4.98 ± 0.27	6.71 ± 0.39	7.35 ± 0.41

1. Significant Yield Increase

Enriched compost led to a significant ($p < 0.05$) yield increase for all tested crops. These effects are attributed to improved nutrient availability, enhanced soil structure, and greater water retention capacity (Nziguheba et al., 2002). For instance, maize yield was tripled, and okra yield more than tripled compared to the control.

2. Crop-Specific Effects

Onion and maize showed a strong response to enriched compost due to their high nitrogen and potassium requirements, abundantly supplied by the organic blend. Okra and pepper exhibited a progressive response correlated with improved soil structure and enhanced phosphorus mineralization.

3. Long-Term Effects (5-Year Forecast)

Trend models show a sustained but asymptotic increase in yields beyond the third year of regular compost application. This trend is supported by the restoration of

the clay-humus complex, reducing erosion and fertility losses (Tittonell & Giller, 2013).

4. Sustainable Yields and Agroecological Resilience

Compost fosters resilient agriculture by reducing reliance on chemical fertilizers, limiting nutrient leaching, and promoting beneficial soil microorganisms (Kyamanywa et al., 2001). These findings are consistent with Bationo et al. (2006) regarding crop response to integrated organic and mineral amendments in the Sahelian zone.

3.5. General Discussion

The results confirm that the integration of *Eichhornia crassipes* and *Urtica dioica*, in combination with animal organic matter rich in mineral elements, synergistically enhances agricultural productivity and soil structure. This finding is consistent with the work of Awasthi et al. (2016), who highlighted that multifunctional composts integratively improve the biological,

chemical, and physical properties of soils. The diversity of organic inputs enabled a gradual release of nutrients and a sustainable improvement of soil porosity, which benefits root growth and water management (Huang et al., 2020). Bones and skeletons served as slow-release phosphorus reservoirs, contributing to long-term performance.

4. Conclusion and Recommendations

Conclusion

The findings of this study clearly demonstrated that the application of an enriched compost composed of local plant biomasses (*Eichhornia crassipes* and *Urtica dioica*) and animal organic matter (chicken manure, cow dung, goat droppings, and bones and skeletons of fish/animals) leads to a significant and sustainable improvement of soil quality in Sahelian regions. This improvement was evidenced by:

- A marked increase in soil organic matter content, pH, and cation exchange capacity (CEC), enhancing nutrient absorption.
- An improvement in soil structural stability and porosity, crucial for limiting erosion, promoting water infiltration, and strengthening root development.
- A significant increase in agricultural yields (ranging from 50 to 80% depending on the crops), with a cumulative effect over successive agricultural seasons.
- A favorable predictive projection of the residual effects of the compost over 5 to 10 years, indicating a strong potential for the sustainable regeneration of depleted soils.

The multifunctional nature of this compost (combining carbon, nitrogen, mineral, and microbial elements) offers a comprehensive and economically accessible agroecological solution for rural areas affected by land degradation and climate change.

Recommendations

1. Disseminate the use of enriched compost among Sahelian farmers through training programs, field school demonstrations, and technical support for local compost production.
2. Promote the ecological valorization of invasive biomasses such as *Eichhornia crassipes* by transforming them into valuable agricultural inputs, thereby contributing to the sustainable management of aquatic ecosystems.
3. Institutional and policy support: Integrate this technique into sustainable soil management, desertification control, and agroecology promotion policies at the communal and national levels.
4. Support applied research to:
 - Refine optimal application rates according to soil and crop types,
 - Evaluate long-term microbiological impacts,
 - Develop biochemical indicators for compost stability.
5. Promote a rural circular economy by encouraging the recovery, treatment, and valorization of domestic, agricultural, and fishing organic waste within a local sustainability framework.

In conclusion, enriched compost derived from locally available natural resources constitutes a powerful lever for ecological intensification, soil restoration, and agricultural resilience in the face of climate change challenges and rural poverty.

Conflict of Interest: The authors declare no conflict of interest.

Acknowledgments: The authors would like to express their sincere gratitude to all individuals and institutions who contributed

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to the successful completion of this research. Special thanks are extended to the local farming communities and cooperatives in the Sudano-Sahelian region of Cameroon for their collaboration and for providing raw materials. We also acknowledge the technical support provided by the Biosciences laboratory teams at the University of Maroua, whose expertise greatly enhanced the analytical phases of this study. This work was made possible through the support of the Sahel Nature Consulting NGO, whose financial and logistical contributions are gratefully acknowledged. Finally, we express our appreciation to all peer reviewers and academic mentors for their constructive feedback and guidance throughout the research process.

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