International Journal of Plant & Soil Science

Volume 38, Issue 4, Page 139-151, 2026; Article no.IJPSS.154131
ISSN: 2320-7035

Impact of Organic Amendments (Dromedary Droppings and Cow Dung) on the Physico-chemical Properties of Three Arid Soils and their Water-holding Capacity

Timbe N'Djédanoum [a*], Ibrahim Pafadnam [a], Abdoulaye Kabre [a], Bétaboalé Naon [b] and Francois Zougmore [a]

[a] Department of Physics, Laboratory of Materials and Environment (LA.M.E), University J. KI ZERBO, UFR/SEA, BP 7021 Ouagadougou, Burkina Faso.
[b] Laboratory of Materials, Heliophysics and Environment (LaMHE), University of Nazi Boni, 01 BP 1091 Bobo Dioulasso, Bukina Faso.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i46037

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/154131

Original Research Article

Received: 10/12/2025
Published: 08/04/2026

Abstract

Soils come from the arid region of Hadjer-Lamis (13°00′00″ N; 15°44′00″ E). Samples were taken in March 2025 at a depth of 0 to 20 cm. At the same time, dromedary droppings and cow dung were collected. The physicochemical characterization of the soils from Dandi, Karal, and Mani was carried out at the Soil, Water, and Plant Laboratory (SWPL) in Chad. The granulometric analysis gives the following results: clay: Dandi

**Corresponding author: E-mail: tdanoum1@gmail.com;*

Cite as: *N'Djédanoum, T., Pafadnam, I., Kabre, A., Naon, B., & Zougmore, F. (2026). Impact of Organic Amendments (Dromedary Droppings and Cow Dung) on the Physico-chemical Properties of Three Arid Soils and their Water-holding Capacity. International Journal of Plant & Soil Science, 38(4), 139–151. https://doi.org/10.9734/ijpss/2026/v38i46037*

(19.5%), Karal (17%), Mani (14%); silt: Dandi (17.5%), Karal (7.5%), Mani (7%); sand: Dandi (63%), Karal (75.5%), Mani (79%). These soils are sandy-loam, chemical analyses indicate, Dandi: MOT (0.655%), CT (0.38%), EC (335 µS/cm), PT (192 ppm), pH (7.64), KT (478.00 mg/kg), CEC (13.34 meq/100 g); Karal: MOT (0.617%), CT (0.358%), EC (687 µS/cm), PT (279 ppm), pH (6.28), KT (994.00 mg/kg), CEC (24.50 meq/100 g). Mani: MOT (0.519%), CT (0.301%), EC (183 µS/cm), KT (384 ppm), pH (6.26), CEC (11 meq/100 g). dromedary droppings: MO (5.20%), pH (7.30), NT (0.033%), potassium (39 mg/l), PA (151.97 mg/kg), Na (86.50 mg/l), EC (2960 µS/cm), Cu (9.60 mg/l), Ca (750 mg/l); cow dung: OM (190 mg/kg), pH (9.2), NT (16 mg/kg), potassium (1.1 cmol/kg), PA (18.2 mg/kg), Na (0.1 cmol/kg), EC (250 µS/cm), Cu (8.1 mg/l), Ca (5 cmol/kg). The application of these organic amendments improves structure, porosity, and organic matter in the soil.

Keywords: Soil; arid; dromedary droppings; cow dung; amendment; organic matter; retention.

1. Introduction

The strong demographic growth observed in sub-Saharan Africa is leading to a significant increase in food requirements. In this context, long fallow periods are gradually disappearing in favour of shorter rest periods and more sedentary forms of agriculture (Bationo et al., 2007). The objective of achieving food self-sufficiency remains central for several countries on the continent, and those of sub-Saharan Africa are fully engaged in this dynamic. In the face of rapid population growth, both at the African and regional levels, increasing agricultural production appears indispensable (Ongoma et al., 2025; Sayouti & Mekki, 2015). To achieve this, a combination of measures is required: expansion of cultivated areas, improvement of soil fertility (Traore, 2009), better management and valorisation of water resources, greater diversification of agricultural production, strengthening of food crisis prevention and management mechanisms, technical support for producers, and training in promising agricultural value chains.

Food self-sufficiency would represent a major advantage for all African countries, particularly those of the Sahel, which are regularly confronted with crisis situations. The Sahel is characterised by a particularly harsh climate, notably marked by low and irregular rainfall as well as poor soils (Yacouba et al., 2018). Despite the efforts made by actors in the agricultural sector, yields vary greatly from one year to another depending on factors such as rainfall, drought, strong winds or locust invasions. Soils also display considerable spatial and temporal variability. Apart from certain favoured areas-plains, lowlands and depressions-aridity remains a dominant characteristic. As these soils are exploited for various uses, they gradually become depleted. In general, a large proportion of land in sub-Saharan Africa suffers from low natural fertility, as a result of constraints specific to each agro-ecological zone (Luciens et al., 2014). These limitations are key factors influencing agricultural production (Luciens et al., 2012; Motsi et al., 2025), fertility being defined as "the capacity of an environment to ensure production", taking into account its various properties. Chad, a landlocked Sahelian country located between latitudes 7° and 24° North and longitudes 13° and 24° East, is subject to a hot continental climate. In Chad, rainfall amounts vary greatly from north to south, ranging between 100 and 1,200 mm per year. This disparity directly influences agricultural systems, especially as rainfall shows high interannual variability and is frequently associated with the risk of drought. The country therefore faces significant climatic hazards that strongly affect agricultural production and food supply. The Chadian population is estimated at 16, 722,196 inhabitants (INSEE, 2021), with a demographic growth rate of 3.30%. Among this population, 44.2% are affected by some form of food insecurity, whether temporary or persistent. Agriculture and livestock farming constitute the pillars of the national economy. The agricultural sector occupies a strategic place in the country's development: it contributes approximately 23% of GDP, of which 20% comes from food crop production and 3% from cash crops such as groundnuts, cotton or gum arabic. It is also the main source of employment, engaging nearly two thirds of the working population, among whom women are in the majority. The second essential contribution of the agricultural sector lies in food production, which directly addresses the challenges of food insecurity and poverty, particularly acute in Chad due to frequent shortages. A third major function of agriculture concerns the supply of raw materials for national agri-food industries. The majority of actors in this sector are family farms which, for several decades, have been facing various constraints that have led to a marked decline in yields (Nyore et al., 2023). Among these constraints is the progressive degradation of soil fertility (Kanté, 2001), exacerbated by certain fertilisation and amendment practices that alter soil properties (Pernes-Debuyser & Tessier, 2002; Ognalanga et al., 2017; Kpera et al., n.d.; Bigorre, 2000). To restore and maintain soil fertility, several actions are required: the application of organic fertilisers (manure, compost, plant residues) (Blanchard, 2010) and mineral fertilisers (NPKSB, urea), the establishment of fallow periods of varying length, the promotion of cover crops or nitrogen-fixing forage crops in order to sustainably improve soils and yields, as well as the training of farmers in simple, low-cost techniques combining erosion control and the addition of organic matter at the plot level.

This study proposes a comparative analysis of soils from the three sites mentioned, in order to provide an additional contribution to the understanding of their physico-chemical characteristics. It highlights their properties in relation to fertilisation practices, as well as their behaviour with respect to water: affinity, retention capacity, circulation and soil-water interactions.

2. Materials and Methods

2.1 Location of the Sample Collection Sites

The study was carried out in three localities of the Hadjer-Lamis region: Karal, Dandi and Mani. The Hadjer-Lamis region is located at 13°00'00" North latitude and 15°44'00" East longitude, and covers an area of 31,426 km². The geographical coordinates of the three localities are as follows: Dandi, 12°48.954' North latitude and 14°40.722' East longitude, with an average altitude of 284 m; Karal, 12°52.752' North latitude and 14°45.507' East longitude, with an average altitude of 276 m; Mani, 12°44.622' North latitude and 14°41.155' East longitude, with an average altitude of 285 m. The climate of the Hadjer-Lamis region is of the Sahelian type, characterised by a long dry season extending from October to May, followed by a rainy season lasting approximately four months. The months of July and August record the highest rainfall, with monthly precipitation ranging from 80 to 180 mm and an annual average close to 450 mm. Monthly maximum temperatures range between 35 and 45 °C, while minimum temperatures vary between 11 and 22 °C. The hottest periods correspond to the months of March, April, May and June, whereas December, January and February are the coolest (Timbé et al., 2023a).

2.2 Sampling and Laboratory Analysis of Manures and Soils

Manures: These consisted of dromedary droppings and caw dung. The analyses were carried out at the Soil-Water-Plant Analysis Laboratory (SWPAL) in N'Djamena (Chad). The samples were collected in the Hadjer-Lamis region in March 2025, after which they were air-dried for one week (Ognalanga et al., 2017) and then ground before chemical analysis. The pH of each sample was measured by electrometry using a sample to water ratio of 1: 2 (w/v). Organic carbon content was determined by dry combustion (Ng et al., 2025), while total nitrogen was assessed using the micro-Kjeldahl method (Bremner, 1996). The samples were then digested in a mixture of perchloric and nitric acids, after which available phosphorus was determined using the vanadomolybdate yellow method (Olsen & Dean, 1965). Potassium and sodium were measured using a flame photometer, whereas calcium and copper were quantified by atomic absorption spectrometry (AAS).

Soils: Soil samples were collected in March 2025 from different locations and soil horizons (0-20 cm). This choice of depth is explained by the fact that these zones correspond to the soil layers where roots develop, ensuring plant anchorage and providing the essential elements for growth: heat, water, and nutrients. It is also within these horizons that the concept of soil fertility is best understood (Touhtouh et al., 2014). The samples were then subjected to various physico-chemical analyses at the Soil-Water-Plant Analysis Laboratory (SWPAL) in N'Djamena (Chad). Particle size distribution refers to the determination of the percentages of minerals that make up the fine earth fraction; it was determined using the densimetric method (Tollen et al., 2018). Chemical analyses were carried out as follows: the maximum water retention capacity (WRC_max) was estimated using the percolation method according to the following relationship:

$$\mathrm{WRC_{max}}(\%) = \frac{(\mathrm{WR}+\mathrm{WI})}{\mathrm{D.M}} \times 100 \tag{1}$$

where WR is the amount of water retained (g), WI is the amount of water initially present in the fresh sample (g), and D.M is the dry matter (g) (Mbonigaba et al., 2009). Electrical conductivity makes it possible to determine the level of soluble salts in water; it is measured using a conductivity meter on a soil suspension with a soil/water ratio of 1:5 after 2 hours of contact, and the reading is taken with a conductivity meter. The results are expressed in µS/cm (Yacouba et al., 2018).

Soil moisture can be estimated using several methods. In our experiment, we chose the gravimetric method, which consists of drying the soil sample at 105 °C for 24 hours. The loss of weight after drying is equal to the soil water content. The values obtained can be expressed as a percentage relative to the weight of the dry or wet sample (Bouchenafa et al., 2014; Buol et al., 2011).

$$\%\ \text{soil moisture} = \frac{(wet\ mass - dry\ mass)}{dry\ mass} \times 100 \quad (2)$$

2.3 Experimental Setup

The experimental setup used is the same as that employed by (Chammari, 2003). The climatic chamber is regulated according to the following set points: the initial water content, temperature and relative humidity are respectively 8%, 30°C and 48%. Several PVC tubes (diameter, D = 4 cm; height, h = 15 cm), several Petri dishes, a metal ruler, adhesive tape and a drying oven are prepared.

2.4 Soil Preparation and Filling of the PVC Tubes

The objective is to amend three arid soils to a given organic matter content. The required materials are as follows: soil samples, distilled water, powders of dromedary droppings and cow dung, a spatula, a balance, a drying oven and airtight containers. The procedure is as follows: Place the soil in the drying oven at 105 °C for approximately 48 h prior to handling, then allow the soil to cool for about thirty minutes. This duration may vary depending on the quantity of soil required for the operation, but it should be sufficiently short to limit rehydration through absorption of atmospheric moisture. A quantity of the dry soil is then taken and placed in an airtight container. The preparation of the soil columns involves several stages: grinding the air-dried dromedary droppings and cow dung (organic materials) into powder, and measuring the masses of the empty PVC tubes and Petri dishes. To obtain the control soil samples, a sufficient given quantity of soil taken from the drying oven and allowed to cool is mixed with 8% distilled water to obtain a homogeneous mixture. For the preparation of the amended soil, the mass of soil is determined according to the number of PVC tubes required. Thus, for a given mass of soil, 4% of organic matter powder (cow dung or dromedary droppings) is first added and mixed until homogeneous; subsequently, 8% distilled water is added and mixing is continued until complete homogeneity is achieved.

Once this step is completed, the samples to be placed in the climatic chamber can be prepared. Filling of the PVC tubes begins with, on the one hand, the control samples and, on the other hand, the amended samples. Compaction is carried out flush with the rim at both ends of the tubes; one end is sealed with adhesive tape to prevent moisture loss. In this way, the soil columns are prepared.

A small quantity of soil remaining after preparation is kept in order to determine its water content. For this purpose, the mass of the moist soil and the dry mass after oven-drying at 105 °C are determined.

- Fick's law: $J = -D\frac{\partial\theta}{\partial z}$ (3)

Where *J* is the water diffusion flux in the soil, *D* is the diffusion coefficient, and $\frac{\partial\theta}{\partial z}$ is the water content gradient.

- Darcy's law: $q = -K(\theta)\frac{\partial h}{\partial z}$ (4)

$K(\theta)$, is the hydraulic conductivity, $\frac{\partial h}{\partial z}$ is the hydraulic head gradient.

- Richards' equation: $\frac{\partial\theta}{\partial t} = \nabla.[K(\theta)(\nabla \text{h} + 1)]$ (5)

3. Results and Discussions

3.1 Results

Table 1. Mineral proportions of the samples

	Localities			
	Dandi	**Karal**	**Mani**	
Parameters	**Value**			**Methods**
Sand (%)	63	75.50	79	The densimetric method
Silt (%)	17.50	7.50	7	(Tollen et al., 2018)
Clay (%)	19.50	17	14	

Table 2. Proportions 1 of selected chemical elements in the three soils and their standard values

	Localities				
	Dandi	**Karal**	**Mani**		
Parameters	**Value**			**Standards**	**Methods**
TOM (%)	0.655	0.617	0.519	3.6 – 6.5	The organic carbon content multiplied by 1.724 (Walkley and Black, 1934) gives the organic matter content
TC (%)	0.380	0.358	0.301	1.26 – 2.5	Dry combustion (Nelson & Sommers, 1996)
MC (%)	2.85	4.52	2.93	------	gravimetric (Bouchenafa et al., 2014)
EC (µS/cm)	335	687	183	------	electrical conductivity (Amir et al, 2018)
TN (%)	0.036	0.041	0.029	------	Micro- kjeldahl (Bremner, 1996)
C/N	11	9	10	11 - 15	C/N, ratio is obtained by directly comparing the total carbon content to the total nitrogen content (Timbé et al., 2023a).
TP (ppm)	192	279	384	0.2 - 0.23 ($g.kg^{-1}$)	Olsen et Sommers, (1965)
AP (ppm)	2.02	5.50	9.72	3 - 8	

Legends: TOM: Total Organic Matter; TC: Total Carbon; TN: Total Nitrogen; AP: Assimilable Phosphorus; TP: Total Phosphorus; C/N: Carbon on Nitrogen; Cond: Electrical conductivity; MC: Moisture content

Table 3. Proportions 2 of selected chemical elements in the three soils and their standard values

		Localities				
		Dandi	**Karal**	**Mani**		
Parameters		**Value**			**Standards**	**Methods**
TP (mg/kg)	TK	478.00	494.00	324	3700	Fluoronitroperchloric acid (Howeler, 1996)
EB (meq/100g)	Ca^{2+}	2.34	8.11	1.44	5 - 8	
	Mg^{2+}	1.25	3.77	0.70	1.5 - 3	
	K^{+}	0.87	0.37	0.67	0.15 - 0.25	
	Na^{+}	0.61	0.25	0.05	0.3 - 0.7	
SB (meq/100g)	S	5.07	12.50	2.86	7.50 - 15	$S = \sum_n X^{n+}, X \in \{Ca,\ Mg,\ K,\ Na\}$, $n = \{1,\ 2\}$ (Timbé et al., 2023a)
SR (%)	V	38	51	26	60 - 90	Saturation Rate, $V = \frac{S}{T} \times 100$, (Timbé N'Djédanoum and al., 2023a)
CEC (meq/100g)	T	13.34	24.50	11	10 - 20	Metson de norme AFNOR NFX31-130 (Saragoni et al., 1992)
Sr	pH-KCl	5.56	5.42	5.2	-----	The pH (pH-water and pH-KCl) (hydrogen potential) was determined using the method of McLean (1982).
	pH-Eau	7.64	6.28	6.26	-----	

Legends: TP: Total Potassium; EB Echangeable Bases SB : Sum of Bases ; SR: Saturation Rate; CEC: Cation Exchange Capacity; Sr: Soil Reaction ; Ca^{2+}: Assimilable calcium ; Mg^{2+} Assimilable magnesium; K^{+}: Assimilable potassium; Na^{+} Assimilable sodium

Normative reference values (Howeler, 1996, 2001; Giroux and Audesse, 2004; Doucet, 2006).

Table 4. Proportions 2 of chemical elements present in the powder of dromedary droppings

Parameters	Values	Methods
AP (mg/kg)	151.97	The method described by Saunders and Williams (1955).
Cu (mg/l)	9.60	Fluoronitroperchloric (Ballot et al., 2016)
Na (mg/l)	86.50	
Ca (mg/l)	750	
K (mg/l)	39	Fluoronitroperchloric acid (Howeler, 1996)
TN (%)	0.033	Micro- kjeldahl (Bremner J. M, 1996)
OM (%)	5.20	The organic carbon content multiplied by 1.724 (Walkley & Black, 1934) gives the organic matter content
OC (%)	3.01	Dry combustion (Nelson & Sommers, 1996)
Cond. Elect. (µS/cm)	2960	Conductivity meter (Amir et al., 2018)
pH-KCl	7.04	Surplus from a suspension of a substrate sample in distilled water at a solid-to-solution ratio of 1:5 (Ognalaga and Itsoma, 2014)
pH-Eau	7.30	

Legends: OM: Organic Matter; Ca: calcium; Na: sodium; OC: Organic Carbon; Cu: Copper; K: potassium

Table 5. Proportion of chemical elements present in cow dung powder

Parameters	Values	Methods
AP (mg/kg)	18.2	The method described by Saunders and Williams (1955)
Cu (mg/l)	8.1	Fluoronitroperchloric (Ballot et al., 2016)
Na (Cmol/kg)	0.1	
Ca (Cmol/kg)	5	
K (Cmol/kg)	1.1	Flame emission spectrometer (Walinga et al., 1989)
TN (mg /kg)	16	Micro- kjeldahl (Bremner J. M, 1996)
OM (mg/kg)	190	The organic carbon content multiplied by 1.724 (Walkley & Black, 1934) gives the organic matter content
OC (mg/kg)	110.4	Dry combustion (Nelson & Sommers, 1996)
Cond. Elect. (µS/cm)	250	conductivity meter (Amir et al., 2018)
pH-KCl	8.39	Surplus from a suspension of a substrate sample in distilled water at a solid-to-solution ratio of 1:5 (Ognalaga and Itsoma, 2014)
pH-Eau	9.2	

- Dandi soil

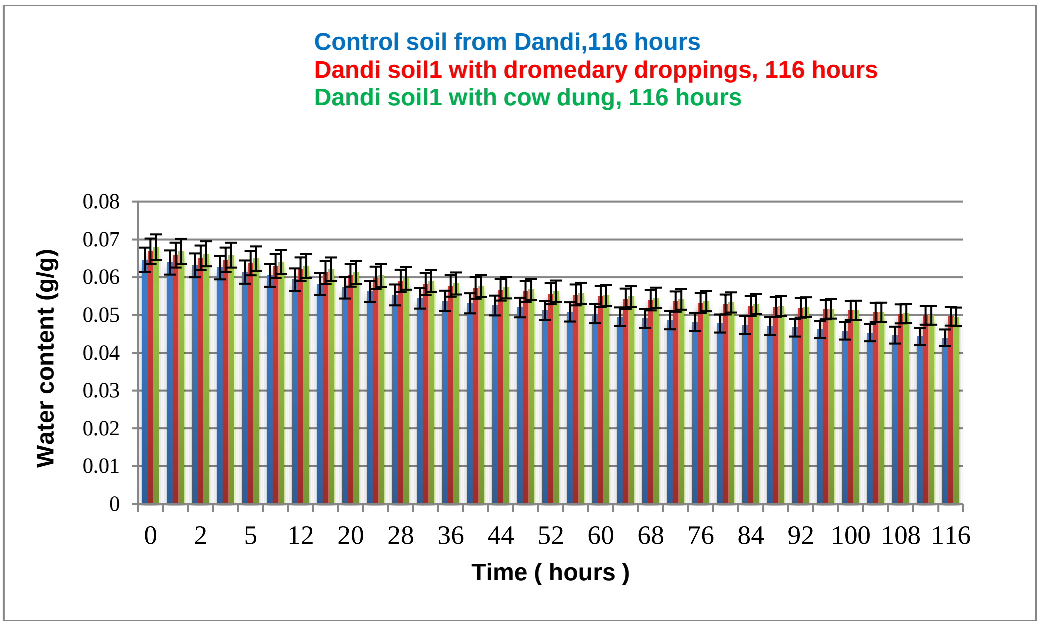

Fig. 1. Comparative evolution of water content in three Dandi soils during drying (116 h) with error bars ±5%, under conditions: $W_{initiale}$ = 8%, RH = 48%, T = 30°C

- Karal soil

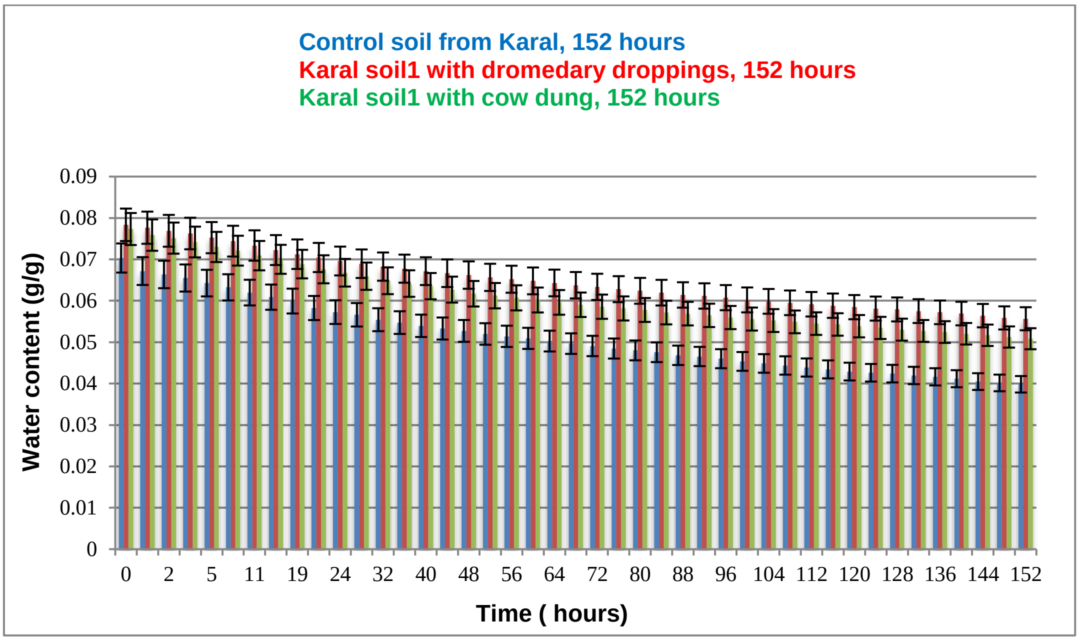

Fig. 2. Comparative evolution of the water content of three Karal soils 1 during drying (152 hours) with error bars ±5%, under the following conditions: $W_{initiale}$ = 8%, RH = 48%, T = 30 °C

- Mani soil

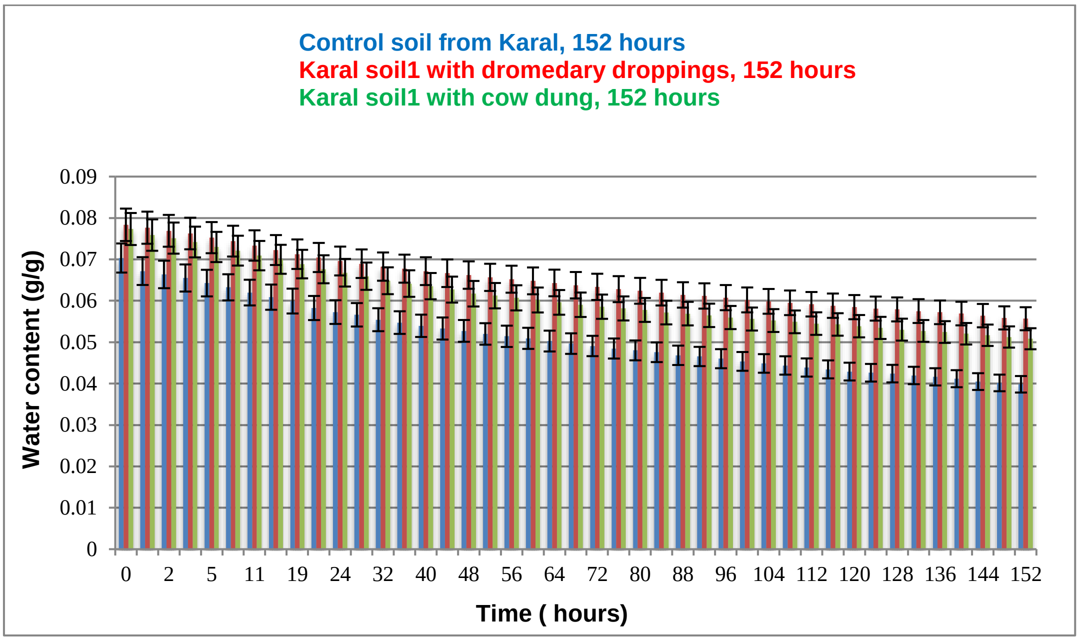

Fig. 3. Comparative evolution of the water content of three soils 1 from Mani during drying (128 h) with error bars ±5%, under conditions: $W_{initiale}$ = 8%, RH = 48%, T = 30 °C

3.1 Discussions

Physical Analysis: Table 1 shows that the Mani soil has the highest average sand content (79%) compared with the other sites. In contrast, the Dandi soil is distinguished by a higher average silt content (17.50%) than those of

Karal (7.50%) and Mani (7%). Dandi also exhibits the highest clay content (19.50%) among the three locations. According to the textural triangle classification (Rafik et al., 2015), these results indicate that all three soils belong to the sandy-loam class (N'Djédanoum et al., 2023b). The obtained textural characteristics are similar to those reported by (Saber et al., 2014) in the Bouskoura region, where the authors observed clay contents ranging from 6.30 to 8.30%, silt from 19.40 to 35%, and sand from 57.30 to 74.30%. However, they differ from the results of (Ognalanga et al., 2017), who studied soils in south-eastern Gabon (Franceville) and identified a fine silt-dominated texture, as well as from (Akassimadou & Yaou-Kouamé, 2014), who reported a silty-clay texture, and from (Temgoua et al., 2015) or those discussed by (Bationo et al., 2007), which are sandy-silty-clay.

Chemical Analyses: In Tables 2 and 3, total potassium contents range from 324 to 494 $mg \cdot kg^{-1}$, with an average of 432 $mg \cdot kg^{-1}$, values significantly lower than the standard of approximately 3700 $mg \cdot kg^{-1}$. The Karal soil exhibits the highest concentration (494 $mg \cdot kg^{-1}$), followed by Dandi (478 $mg \cdot kg^{-1}$) and Mani (324 $mg \cdot kg^{-1}$). Regarding exchangeable bases, Ca^{2+} contents range from 1.44 to 8.11 meq/100 g, with an average of 3.96 meq/100 g, below the reference values (5-8 meq/100 g). Karal stands out with 8.11 meq/100 g, slightly above the standard, whereas Dandi (2.34 meq/100 g) and Mani (1.44 meq/100 g) display low levels. Mg^{2+} contents range from 0.70 to 3.77 meq/100 g, with an average of 1.90 meq/100 g, within the normative range. However, Karal reaches 3.77 meq/100 g, a slightly high value, while Dandi shows a normal content (2.34 meq/100 g) and Mani a low content (0.70 meq/100 g) (Timbé et al., 2023a). For K^+, concentrations vary between 0.37 and 0.87 meq/100 g, with an average of 0.63 meq/100 g, higher than the standard (0.15-0.25 meq/100 g); Dandi (0.87 meq/100 g) and Mani (0.67 meq/100 g) have very high contents, while Karal shows a slightly above-standard level (0.37 meq/100 g). Na^+ contents range from 0.05 to 0.61 meq/100 g, with an average of 0.30 meq/100 g, conforming to reference values (0.3-0.7 meq/100 g). Dandi shows a normal content (0.61 meq/100 g), Karal a slightly low value (0.25 meq/100 g), and Mani a very low content (0.05 meq/100 g).

The sum of exchangeable bases (S) varies from 2.6 to 12.50 meq/100 g, with an average of 6.81 meq/100 g, below critical thresholds (7.5-15 meq/100 g). Karal reaches 12.50 meq/100 g, above the threshold, whereas Dandi (5.07 meq/100 g) and Mani (2.86 meq/100 g) show low to very low levels. Saturation rates generally remain below recommended values. The pH, a key indicator of nutrient availability, varies for pH-water around an average of 6.72, corresponding to a neutral soil. Extreme values range from 6.26 (slightly acidic) to 7.64 (slightly alkaline). This average is lower than that reported by (Rafik et al., 2015) but higher than values obtained by (Akassimadou & Yaou-Kouamé, 2014). The pH-KCl, ranging from 5.42 to 5.62 (average: 5.52), is higher than that observed in the study by (Ognalanga et al., 2017). Organic matter contents (0.519-0.655%) are low compared with (Ognalanga et al., 2017) but remain higher than those observed by (Ouoba et al., 2014). Total nitrogen varies from 0.029 to 0.041% (average: 0.035%), with Karal leading (0.041%), followed by Dandi (0.036%) and Mani (0.029%). Available phosphorus ranges from 2.02 to 9.72 ppm (average: 5.74 ppm, a normal value). Mani has a high content (9.72 ppm), Karal a normal content (5.50 ppm), and Dandi a low value (2.02 ppm). Total phosphorus varies between 192 and 384 ppm (average: 285 ppm). Dandi (192 ppm) is slightly below the standard, whereas Karal (279 ppm) and Mani (384 ppm) are above it. C/N ratios range from 9 to 11, with an average of 10, above recommended values, indicating relatively slow organic matter decomposition. Only Dandi shows a compliant ratio. These values are lower than those reported by (Traoré, 2009). Finally, Cation Exchange Capacity (CEC) varies from 11 to 24.50 meq/100 g, with a normal average of 16.28 meq/100g. Dandi and Mani exhibit compliant CECs, while Karal shows a high value.

Manure Analyses: Table 4 presents the proportions of chemical elements present in dromedary droppings powder. Dromedary droppings exhibits a neutral to slightly alkaline pH (pH-water = 7.30; pH-KCl = 7.04), indicating a dominance of basic cations, in agreement with observations in arid zones (Traoré, 2009; Mando et al., 2005). Its high electrical conductivity (2960 µS/cm) reflects a high content of soluble salts, a characteristic feature of animal excreta originating from arid environments (Kihara et al., 2012). The contents of organic carbon (3.01%) and organic matter (5.20%) confirm the presence of relatively stable organic matter, which is favourable for improving soil structure and water retention (Six et al., 2002). The high level of available phosphorus (151.97 mg/kg) represents a major agronomic advantage in tropical soils that are poor in phosphorus, while the moderate copper concentration (9.60 mg/l) remains below toxicity thresholds.

The results in Table 5 show that cow dung powder has a strongly alkaline pH (pH-water = 9.2; pH-KCl = 8.39), reflecting a dominance of exchangeable bases and a strong alkalinising capacity, in accordance with previous studies on bovine manure (Bationo & Mokwunye, 1991; Palm et al., 2001). The low electrical conductivity (250 µS/cm) indicates low salinity, limiting the risk of salinisation and confirming its suitability for regular application on fragile soils (Traoré, 2009). The low levels of exchangeable sodium (0.1 cmol/kg) rule out any risk of sodification, while the concentrations of copper (8.1 mg/l) and available phosphorus (18.2 mg/kg) remain consistent with values reported for tropical bovine manures (Kihara et al., 2012).

Fig. 1 illustrates the evolution of soil water content (g/g) in the Dandi soil over a period of 116 hours. Error bars represent variability around the mean. Three treatments are compared: the control soil (blue curve), soil amended with dromedary droppings (red curve), and soil amended with cow dung (green curve). Overall, a progressive decrease in water content is observed, corresponding to the drying process. This dynamic can be interpreted in light of the principles of water transport in porous media. Moisture diffusion follows Fick's law, according to which the diffusive water flux J is proportional to the gradient in water content, explaining the gradual migration of water towards drier zones over time. In addition, the temporal evolution of soil water content conforms to the framework of the Richards equation, which combines diffusion and gravitational advection, thereby explaining the observed kinetics of water retention and loss among treatments. Vertical water movement within the soil profile is also governed by Darcy's law, clarifying why soils with improved pore structure or higher water-holding capacity exhibit slower flow rates. In this context, amended soils show higher water contents than control soils, reflecting enhanced water retention associated with the addition of organic matter and modifications to hydrodynamic properties (increased storage capacity and reduced effective conductivity). Soils amended with cow dung even display a slightly higher water-holding capacity than those amended with camel dung, in agreement with observations reported in (Rehman et al., 2020) and proving more effective than what is described in (Ling et al., 2021).

Fig. 2 illustrates the evolution of soil water content in Karal soils amended with two types of organic matter. Error bars indicate the uncertainty associated with the measurements. Three treatments are compared: the control soil (blue curve), soil amended with dromedary droppings (red curve), and soil enriched with cow dung (green curve). Over a period of 152 hours, the control soils show the greatest decrease in water content, revealing a low water-holding capacity in the absence of organic amendment. In contrast, the amended soils maintain higher water contents throughout the experiment, confirming the role of organic matter in improving soil porosity and cohesion, and thus its capacity to retain moisture. Between the two types of amendments, dromedary droppings provides slightly higher water retention than that observed with cow dung. These results are consistent with the conclusions reported by (Peng et al., 2023).

Fig. 3 illustrates the drying kinetics of three types of Mani soils: for each figure, a control soil, a soil amended with dromedary droppings, and another amended with cow dung are presented. The aim of this representation is to assess the effect of organic amendments on the dynamics of soil moisture loss over time. In both figures, observation of the curves shows a progressive decrease in water content for all samples, reflecting the normal drying process. However, the drying rate varies depending on the type of amendment applied. The control soil exhibits rapid water loss, whereas the amended soils retain moisture for a longer period. Among the latter, the soil amended with cow dung displays a slower drying kinetics than that amended with camel dung. These differences reflect the influence of organic amendments on the soil's water-holding capacity. Cow dung, rich in fine and colloidal organic matter, improves soil structure, increases effective porosity, and reduces the rate of desiccation. Dromedary droppings, being more fibrous and less decomposed, also contributes to improving soil structure, but its effect on water retention remains more moderate compared with cow dung. By contrast, the control soil, lacking any amendment, exhibits a coarser structure and low aggregate cohesion, resulting in rapid moisture loss. Overall, the drying kinetics highlight the decisive role of organic amendments in soil moisture conservation. Amendment with cow dung proves to be the most effective in slowing down drying, which constitutes a significant advantage for agricultural production in arid and semi-arid regions. These results are in agreement with several previous studies highlighting that organic matter improves soil structure, stability, and water-holding capacity (Washa, 2020; Ling et al., 2021).

4. Conclusion

The Hadjer-Lamis region is subject to a Sahelian climate of the tropical semi-arid type, marked by strong seasonal variability. It is characterised by a long dry season lasting eight to ten months and a short rainy season concentrated between June and September, with low and irregular annual rainfall generally ranging from 150 to 600 mm. Temperatures are particularly high, frequently exceeding 40 °C at the end of the dry season, which intensifies water stress and contributes to land degradation. Agricultural lands in the region are therefore generally poor and weakly structured. Physico-chemical analyses carried out on soils from the localities of Dandi, Karal and Mani revealed a predominantly sandy-loam texture, associated with a low organic matter content, thereby limiting their water retention capacity. In order to assess the effect of organic amendments on these arid soils, a prior chemical characterisation of cow dung and dromedary droppings was conducted. The soils were subsequently amended with 8% of either organic material and then placed in a controlled climatic chamber maintained at a temperature of 30 °C and a relative humidity of 48%. The results demonstrate that the addition of organic matter, whether cow dung or dromedary droppings, significantly improves the water retention capacity of the studied soils. These organic amendments contribute to improved soil structure and optimisation of soil hydric functions, highlighting their potential as a local, sustainable and appropriate solution for enhancing soil fertility and resilience in the arid environments of Hadjer-Lamis under prevailing climatic constraints.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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