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Research paper

Assessing the Impact of Climate Change on Soil Moisture and Temperature Regimes in Northern Algeria

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ABSTRACT

This study analyzes the effects of long-term climate trends on soil moisture and temperature regimes in the Algiers coastal basin using statistical analyses and the Newhall Simulation Model. Pettitt's test was applied to precipitation and temperature series to detect breaks and identify significant climate changes. Results indicate a clear aridification trend since the mid-1980s, with decreased rainfall and regional temperature increases of approximately 0.8 °C. The Newhall Simulation Model revealed a xeric soil moisture regime and a thermic soil temperature regime at all stations, highlighting the strong influence of rainfall and temperature variability on soil conditions. Due to significant rainfall decline, the subgroup of soil moisture classification shifted from Typic Xeric to Dry Xeric at the Bir Mourad Raïs, Blida, and Koléa stations. An increase in the number of soil dry days instead of moist days was observed for the same stations, while soil moist days instead of dry days decreased. Additionally, the number of days with soil temperatures exceeding 8 °C is about 360 days. These soil moisture and temperature conditions may significantly affect soil water balance, agricultural productivity, and ecosystem stability. Therefore, adaptive strategies should be implemented to maintain soil functionality, productivity, and long-term sustainability under increasing aridity and warming conditions.

Keywords: Soil moisture regime, Soil temperature regime, Climate change, Java Newhall simulation model, Soil classification, Algeria

Soils play a key role in the Earth system, ensuring USDAing vital functions such as water regulation, food production, carbon storage, and biodiversity preservation (FAO, 2015; Lal, 2020). These functions depend strongly on water and temperature dynamics, which control pedogenesis, soil fertility, and resilience to environmental changes (Bünemann *et al.,* 2018). Understanding soil thermal and moisture regimes is essential for evaluating land–atmosphere interactions, agricultural suitability, and ecosystem functioning, particularly in Mediterranean and semi-arid environments that are highly sensitive to climate variability. In recent decades, these regions have experienced significant changes in temperature and precipitation patterns, leading to increased drought frequency, prolonged dry periods, and altered soil water availability (Giorgi, 2006; MedECC, 2020; IPCC, 2021; Essa *et al.,* 2023). Despite the importance of soil climate regimes for land management and climate impact assessments, comprehensive analyses integrating long-term climatic variability with soil thermal and moisture classification remain limited in Algeria. Most existing studies have focused on climate variability analysis (Meddi *et al.,* 2010; Taibi *et al.,* 2017; Taibi *et al.,* 2022), drought processes (Merabti *et al.,* 2023; Haied *et al.,* 2023), with less attention given to their implications for soil regimes.

Therefore, this study was undertaken to fill this gap by characterizing the spatial and temporal variability of soil thermal and moisture regimes under climatic conditions in Northern Algeria. Different approaches have been developed to assess soil moisture and temperature regimes and their impacts especially in agriculture (Dar *et al.,* 2018; Sunkad *et al.,* 2023). In this study, the Newhall

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Simulation Model (Newhall, 1972; Newhall & Berdanier, 1996) is used, as it has been widely applied in numerous studies worldwide (Tavernier, 1976; Tavernier & Van Wambeke, 1976; Billaux, 1978; Van Wambeke, 2000; Winzeler *et al.,* 2013; Karaca *et al.,* 2022). Hence, the objective of this study is to assess long-term climatic trends and their effects on soil temperature and moisture regimes, contributing to sustainable land use planning, agricultural adaptation strategies, and climate-resilient resource management.

MATERIALS AND METHODS

Study area and data set

The study area is located in northern Algeria, at the core of the The Sahel of Algiers and the Mitidja Plain. It extends between the Mediterranean coastline and the Blida Atlas Mountains (Fig. 1).

The region has a warm Mediterranean climate with mild, wet winters and hot, dry summers. Average annual temperature is about 17 °C, with rainfall between 600–750 mm. Coastal zones show moderated temperatures due to maritime influence, while inland and higher areas like Blida exhibit stronger daily and seasonal contrasts.

To identify the soil moisture and temperature regimes in the study area, five rainfall stations have been selected based on the availability and quality of their climatic data series (Table 1). These data were obtained from the National Agency of Water Resources (ANRH). For temperature analysis, data from the “Dar El Beida” meteorological station, spanning 1950–2016 and provided by the National Office of Meteorology (ONM), were used. The monthly temperature and rainfall data from each station are used to determine the soil moisture and temperature regimes.

Table 1: Geolocation of the stations and observation period

ID	Stations name	Latitude	Longitude	Study period
020509	Bir Mourad Rais	36.74° N	3.05° E	1951-2010
020632	Reghaia	36.74° N	3.34° E	1972-2011
021116	Blida	36.48° N	2.83° E	1968-2010
021201	Fer à cheval	36. 68° N	2.81° E	1968-2011
021211	Koléa	36.64° N	2.77° E	1970-2010

Methods

The Pettitt statistical test and the Java Newhall Simulation Model (JNSM) were applied to assess the effects of climatic trends on soil temperature and soil moisture regimes. The Pettitt test (1979) is widely used to identify significant change points in long-term climatic series (Meddi *et al.,* 2010; Taibi *et al.,* 2017). The JNSM version 1.6.1 (NRCS, 2016) was employed to identify soil temperature regimes and soil moisture regimes using monthly rainfall and temperature data as required climatic inputs. The JNSM computes potential evapotranspiration (PET) and soil water balance within an idealized 200 mm soil profile (Van Wambeke, 2000). The model outputs included:

- Soil temperature regime (e.g., thermic, hyperthermic) and soil moisture regime (e.g., aridic, xeric, ustic) following USDA Soil Taxonomy definitions (USDA, 2014).
- Number of days when the soil temperature (ST) is ≤5°C, 5°C-ST-8 °C and ≥ 8 °C.
- Number of days when the soil moisture control section (SMCS) is moist, partially moist and dry.

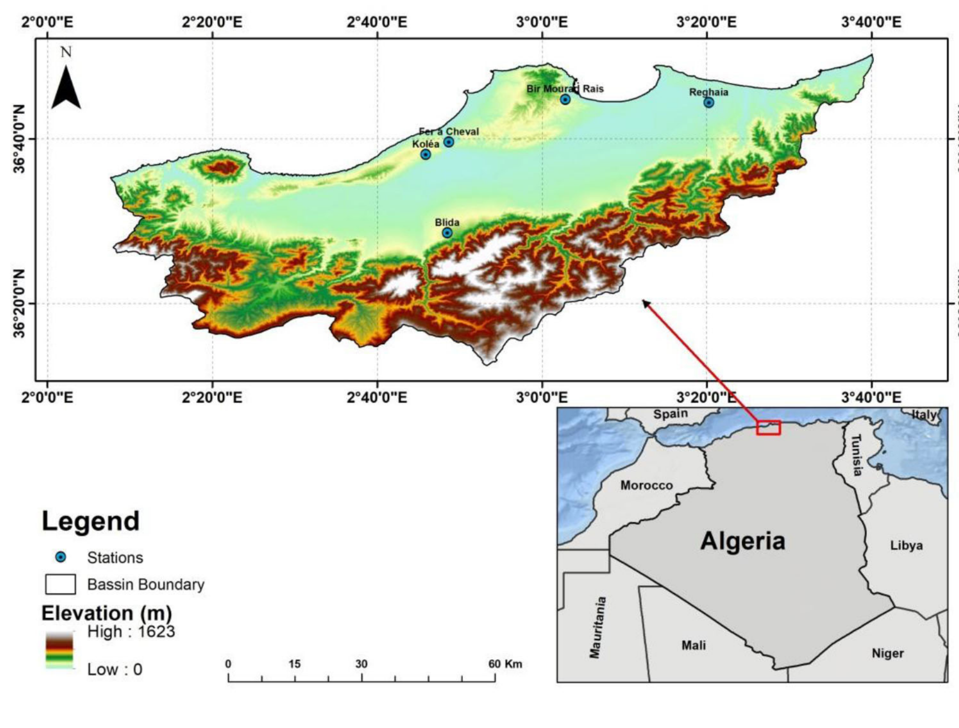

Fig. 1: Location of the study area and rainfall stations

RESULTS AND DISCUSSION

Temporal variability analysis

Statistical analysis of precipitation using the Pettitt test (1979) highlighted significant change in rainfall regimes in the study area (Table 2). Showed a notable break corresponded with a 19% decrease in rainfall since 1986 at Bir Mourad Raïs stations over the study period (1951-2010). More pronounced reductions were observed at Blida and Koléa since 1986, with rainfall declines of 41% and 27%, respectively. However, no significant rainfall change is detected in Réghaïa and Fer à Cheval stations. The Decline in precipitation confirms the region vulnerability's to climate change as reported by previous studies (Taibi *et al.,* 2013; Meddi *et al.,* 2010).

Table 2: Pettitt's statistical Analysis results at 5% significant level

Stations		P-value	Year of breakpoint	Mean before	Mean after	Difference
Rainfall stations	Bir Mourad Rais	0.015	1986	832.6 mm	676.2 mm	-19%
	Blida	< 0,0001	1986	826 mm	485 mm	-41%
	Koléa	0.010	1986	680.1mm	495.2mm	-27%
	Fer à cheval	0.425	-	-	-	-
	Reghaia	0.142	-	-	-	-
Temperature station	Dar El Beida	< 0,0001	1984	17.3°C	18.1°C	0.8°C

Table 3: mean precipitation, mean potential evapotranspiration (PET), soil moisture regime and soil temperature regimes at each station before and after 1986

Stations	Mean precipitation (mm)		Mean PET (mm)		Soil temperature regime		Soil moisture regime	
	Before	After	Before	After	Before	After	Before	After
Bir Mourad Rais	832.6	676.2	894.0	951.45	Thermic	Thermic	Xeric subgroup: typic xeric	Xeric subgroup: dry xeric
Blida	826	485	906.4	972.5	Thermic	Thermic	Xeric subgroup: typic xeric	Xeric subgroup: dry xeric
Koléa	680.1	495.2	884.8	949.48	Thermic	Thermic	Xeric subgroup: typic xeric	Xeric subgroup: dry xeric
Reghaia	644,48		898,1		Thermic		Xeric	
Fer à cheval	581		877,9		Thermic		Xeric	

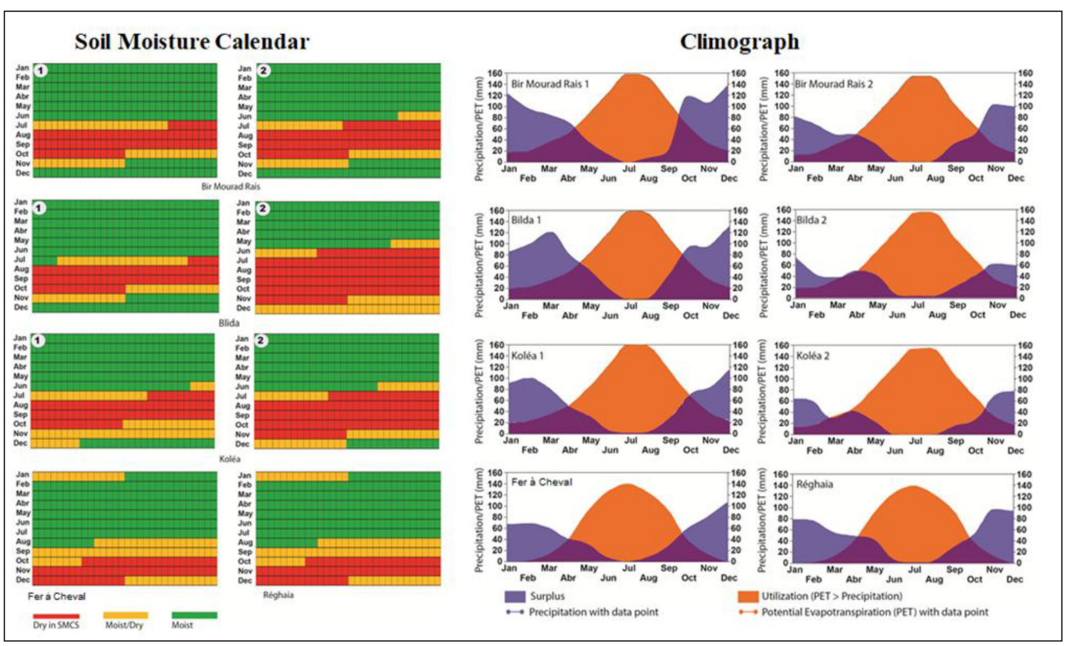

Fig. 2: Soil moisture calendar and climograph of the studied stations
(1: means period before the break point, 2: means period after the break point, one soil calendar and climograph is provided for Fer à cheval and Reghaia stations)

Table 4: Number of soil moist and dry days and number of soil temperature days ≥ 8°C, before and after 1986.

Stations	Bir Mourad Rais		Blida		Koléa		Reghaia	Fer à cheval
Period	Before	After	Before	After	Before	After	over the study period	
Number of soil moist days	225	218	229	172	198	185	196	196
Number of soil dry days	83	91	80	125	86	123	84	82
Number of soil temperature days ≥ 8°C	360	360	360	360	360	360	220	220

Statistical analysis of temperature over the period 1950-2016 indicated an increase of about 0.8 °C since 1984 (Table 2), consistent with previous studies highlighting the effects of global warming at both regional and local scales (Giorgi *et al.,* 2006; IPCC, 2021; Taibi *et al.,* 2022).

Analysis of soil moisture and temperature regimes

Soil moisture and temperature regimes were determined using the Java Newhall Simulation Model (Fig. 2). To assess the effect of climate variability on soil conditions in the study area, model output parameters were compared before and after 1986; the date of break detected by Pettitt statistical test except for Reghaïa and Fer à Cheval stations. Results showed that all stations exhibit a xeric soil moisture regime and thermic soil temperature regime (Table 3). However, due to a significant rainfall decline, the subgroup shifted from Typic Xeric to Dry Xeric at Bir Mourad Raïs, Blida, and Koléa stations after 1986. This classification of soil highlights the strong influence of rainfall and temperature variability on soil moisture regime. Although no statistically significant changes in precipitation were detected at Reghaia and Fer à cheval stations, the results nonetheless indicate a xeric and thermic regime.

The number of days when soil moisture is wet (Fig. 2) decreased from 225 to 218 days at Bir Mourad Raïs, from 229 to 172 days at Blida and from 198 to 185 days at Kolea (table 4). In contrary, the number of days when soil moisture is dry increased from 83 to 91 days, 80 to 125 days and 86 to 123 days, respectively, at Bir Mourad Raïs, Blida and Koléa stations. These results confirm the shift from Typic Xeric to Dry Xeric soil moisture regime.

The number of days when soil temperatures exceeded 8 °C is about 360 days at Bir Mourad Raïs, Blida, and Koléa, both before and after 1986, confirming the Thermic regime. Also, the soil temperature regime remains classified as Thermic for Réghaïa and Fer à Cheval stations, despite the shorter duration of approximately 202 days.

Such conditions of soil moisture and temperature may affect significantly soil water balance, agricultural productivity, and ecosystem stability in these areas. The prolongation of dry periods, particularly in Blida and Koléa, highlights the tangible effects of climate change, with an increased drought frequency, as demonstrated by both local and regional previous studies (Merabti *et al.,* 2023; Haied *et al.,* 2023; Barredo *et al.,* 2018; Essa *et al.,* 2023; Douvis *et al.,* 2023).

Verheye & de la Rosa (2009) and Zdruli *et al.,* (2010) reported that, soils of meditteranean region are characterised by xeric soil moisture regime and thermic or occasionally mesic temperature regime. Recent studies indicated that climate change is exacerbating xeric conditions through increased temperatures, altered precipitation patterns, and a heightened frequency of drought events, which collectively intensify soil degradation processes (FAO, 2022; IPCC, 2021). Crops exposed to combined heat and water stress experience reduced stomatal conductance, impaired photosynthesis, shortened phenological cycles, and decreased reproductive success, resulting in substantial yield losses (Lamaoui *et al.,* 2018; Dar *et al.,* 2018; Brar *et al.,* 2022). Moreover, the accelerated mineralization of organic matter under high thermal conditions further reduces soil fertility and structural stability, increasing susceptibility to erosion and salinization, particularly in irrigated systems (Lal, 2003; Onwuka *et al.,* 2018). These processes contribute to long-term land degradation and desertification, posing serious risks to food security in dryland regions (FAO, 2022).

CONCLUSION

The objective of this study is to assess the effects of climate change on soil moisture and temperature regimes in a region of northern Algeria by combining statistical analysis of climate variability with Newhall model simulations. The finding revealed a clear aridification trend since the middle 80's, with reduced rainfall and regional temperature increases of about 0.8 °C. This situation affected significantly the soil moisture and temperature of the study area characterizing them as Xeric and Thermic regime.

In this context, adaptive strategies such as the use of drought and heat-tolerant crop varieties, improved irrigation efficiency, organic matter management, and agro-ecological practices should be implemented to enhance the resilience of agricultural systems in xeric and thermic environments. Additionally, identifying appropriate land-use, soil conservation and agroforestry practices can support soil functionality, productivity, and long-term sustainability under increasing aridity and warming conditions.

Finally, further investigations are recommended to address limitations in the spatial and temporal climatic data availability. Furthermore, anthropogenic pressures and changes in agricultural practices should be considered to better assess their impacts on soil moisture and temperature regimes.

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