



Investigation of Underground Soil Temperature and Soil Thermal Properties in Federal Polytechnic Ede South Campus

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Abstract – This study investigated the spatial and temporal variation of underground soil temperature and associated thermal properties at the Federal Polytechnic Ede South Campus, Osun State, Nigeria. Twenty sampling locations were established at approximately 20m intervals in an area of 7029.43 m², and soil samples were collected at 0.80 m depth for textural classification. Soil temperatures were monitored over seven days during morning, afternoon, and evening periods, while thermal radiation was estimated using the Stefan–Boltzmann relationship. GIS techniques were subsequently used to visualize the spatial distribution of soil texture, temperature, and radiation. Soil temperature measurements shows significant temporal and spatial variations, with temperatures generally increasing from morning to afternoon and decreasing slightly during the evening period. The highest temperature recorded was 34.7°C, while the lowest temperature recorded was 24.2°C. Underground temperatures varied between 25.90 and 31.00°C on daily basis. Radiation values varied spatially and temporally, generally increasing with temperature. Sandy locations exhibited faster thermal responses, whereas clay- and silt-rich areas showed relatively greater thermal stability. The Geographic Information System (GIS) maps revealed that areas with higher sand contents generally corresponded to zones of higher temperature (31°C) and radiation intensity (284.90 w /m²k⁴), while locations with higher clay and silt contents exhibited relatively stable thermal conditions due to their greater moisture retention and heat storage capacities. This study provides valuable baseline information for geotechnical engineering, environmental studies, agricultural planning, geothermal investigations, and sustainable land-use management. Future investigations should extend monitoring of soil's thermal properties across wet and dry seasons.

Keywords: Geospatial, Radiation, Soil Thermometer, Stefan–Boltzmann, Temperature, Thermal.

1. Introduction

Soil temperature is an important component of the terrestrial energy balance and is influenced by climatic conditions, soil texture, moisture content, bulk density, compaction, and the thermal properties of the soil. The principal thermal properties specific heat capacity, thermal conductivity, thermal diffusivity, and thermal admittance control the storage and movement of heat through the soil profile. Thermal conductivity determines the capacity of soil to transmit heat, while thermal diffusivity describes the rate at which temperature changes propagate through the soil. Recent studies confirm that soil water content, texture, porosity, and bulk density are major controls on thermal conductivity and heat transfer (Xiong *et al.*, 2023; Wu *et al.*, 2025).

Solar radiation is the primary external energy source driving variations in soil temperature. During the day, incoming radiation warms the soil surface, while heat is progressively transferred downward (Sauer & Horton, 2005; Holmes *et al.*, 2008). Consequently, temperature fluctuations generally decrease with depth and occur later as depth increases. Soil moisture also modifies this process because water alters heat storage and transmission within the soil. Soil structure and texture influence water retention and heat conduction, making spatial differences in soil composition important when evaluating underground thermal conditions (Food and Agriculture Organization (FAO), Sepaskhah & Mazaheri-Tehrani, 2024).

Understanding these thermal variations is relevant to agriculture, environmental management, geotechnical engineering, building foundations, and renewable-energy development (Sauer *et al.*, 2020; He *et al.*, 2018; Zhang & Wang, 2017). In particular, soil thermal conductivity is a key parameter in the design and assessment of ground-source heat-pump and underground thermal-energy systems because it influences heat exchange between the ground and engineered systems (Xiong *et al.*, 2023; Saleem *et al.*, 2024).

Recent research has demonstrated that soil thermal conductivity is not a fixed property but varies according to both intrinsic soil characteristics and changing environmental conditions. Wu *et al.* (2025), in a comprehensive review of experimental data and predictive models, reported that soil thermal conductivity generally increases with increasing water content, degree of saturation, dry bulk density, and quartz content, while factors such as greater porosity and higher clay-particle proportions can reduce thermal conductivity. The authors further emphasized that soil thermal conductivity

exhibits considerable temporal and spatial variability because soil moisture, temperature, density, and other environmental conditions vary across locations and through time.

Similarly, Xiuling *et al.* (2024) reviewed advances in soil thermal conductivity research and identified thermal conductivity, thermal diffusivity, and volumetric heat capacity as major parameters for describing the thermal regime and heat-transfer behaviour of soils. Their review showed that different soil types respond differently to changes in moisture, density, temperature, texture, and other physical conditions. The study also highlighted the importance of appropriate field and laboratory measurement techniques because predictive models developed for one soil type or environmental condition may not necessarily provide reliable estimates under different conditions. This finding demonstrates the importance of obtaining site-specific measurements when characterizing the thermal behaviour of subsurface soils.

Despite these advances, there remains a need for site-specific investigations that combine measurements of underground soil temperature and thermal properties with geospatial analysis, particularly within institutional environments in southwestern Nigeria. Much of the existing literature has focused on general relationships between soil thermal properties and physical variables, laboratory-based prediction models, agricultural fields, cold-region engineering, or geothermal-energy applications. Comparatively limited information is available on the spatial distribution of underground soil temperature and selected thermal properties within the Federal Polytechnic Ede South Campus. This creates a knowledge gap because differences in soil texture, moisture content, compaction, vegetation, land use, surface cover, and depth can produce spatial variations in the thermal condition of the subsurface.

Therefore, a geospatial investigation provides an appropriate approach for determining how underground soil temperature and selected thermal properties vary from one sampling location to another and with depth. Mapping these variations can provide a clearer representation of the subsurface thermal environment than isolated point measurements. It can also establish baseline information that can subsequently be used in geotechnical investigations, environmental studies, infrastructure planning, and preliminary evaluation of ground-based thermal-energy applications.

Accordingly, this study investigates the spatial distribution of underground soil temperature and selected soil thermal properties at the Federal Polytechnic Ede South Campus, Osun State, Nigeria. The study examines variations in the measured parameters across sampling locations and soil depths and applies geospatial techniques to characterize their spatial distribution. The results provide site-specific baseline information on the thermal behaviour of the campus subsurface and contribute to improved understanding of the relationship between underground soil temperature, soil thermal properties, and spatial variability. The findings also provide useful preliminary information for geotechnical assessment, environmental management, and future investigations into the feasibility of ground-based thermal-energy applications at the study site.

2. Materials and Method

2.1 Soil temperature measurement

Soil sampling is a fundamental procedure in geotechnical, environmental, and geospatial studies. It provides essential information about soil properties, composition, and spatial variability. Systematic sampling at defined intervals allows for proper representation of the study area and supports accurate analysis and mapping. For the purpose of this study, soil samples were collected at a depth of 0.80m below the ground level at regular intervals of 20m in order to assess sub-surface soil characteristics and their spatial distribution.

The following materials were used: soil auger or hand digger, measuring tape (≥ 20 m), GPS device (for location recording), sample bags or containers, marker or labeling tags, gloves, safety boots and field notebook and pen. A baseline was established across the study area. Using a measuring tape, sampling points were marked at 20m intervals along the line. Distances between sampling points were carefully measured to maintain consistency. Pegs or markers were used to identify each sampling location. At each marked point, a hole was dug vertically to a depth of 0.80m using a soil auger. Care was taken to avoid contamination from surface soil. Soil samples were collected specifically from the 0.80m depth. Each sample was placed into a clean sample bag. Each sample was properly labeled with: Sample point number, depth (0.80m), date of collection & location (since GPS was used). Relevant details for each sampling point were recorded in a field notebook, including observations about soil color, texture, and moisture condition. Soil samples were successfully collected at regular 20m intervals across the study area at a depth of 0.80m.

2.2 Soil temperature measurement

Soil temperature is an important environmental parameter that influences plant growth, microbial activity, and heat transfer processes within the subsurface. Accurate measurement of soil temperature at different depths is essential for geotechnical studies, agricultural planning, and environmental monitoring. An infrared thermometer is a non-contact device commonly used to measure surface temperature by detecting thermal radiation emitted by an object. For the purpose of this study, the instrument was adapted to estimate soil temperature at a depth of 0.80 m below ground level. The aim of this experiment is to measure the soil temperature at a depth of 0.80 m below ground level using an infrared thermometer. The following materials were used: infrared thermometer, protective gloves & field notebook and pen.

The site was prepared as stated in 2.1 and temperature of the established points was taken after digging to depth 0.80m below the ground level. Care was taken to maintain the integrity of the soil profile and avoid excessive exposure to

sunlight, which could alter the temperature. The infrared thermometer was directed at the exposed soil surface at the bottom of the hole (0.80 m depth). The device was held steady, ensuring proper alignment and distance according to the manufacturer's instructions. Multiple readings were taken to improve accuracy, and the average value was recorded as the soil temperature at that depth. Temperature measurements were taken quickly after excavation to minimize temperature changes, proper handling and calibration of the infrared thermometer was ensured. The temperature was taken first thing in the morning as early as 6:30 am and late in the evening by 6:30 pm. All readings were recorded immediately in a field notebook, along with the time of measurement and environmental conditions.

2.3 Radiation

Soil radiation in this study can be interpreted using the Stefan–Boltzmann law, which states that thermal radiation emitted by a surface is proportional to the fourth power of its absolute temperature.

$$\text{Radiation formula (E)} = \sigma T^4 \quad (1.0)$$

E= Total radiant energy emitted per unit surface area of a body per unit time (W/m²).

σ = Stefan–Boltzmann constant & T = Temperature.

$$\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4 \quad (2.0)$$

Because soil is not a perfect blackbody, emissivity must be considered when estimating its long-wave radioactive emission (Eqn. 3). Thermal radiation is an important component of the surface-energy balance because radioactive exchanges contribute to the partitioning of energy into sensible, latent and ground heat fluxes, thereby influencing soil temperature (Li *et al.*, 2024). Recent research further demonstrates that changes in vegetation, surface albedo and incoming radiation can substantially modify soil thermal conditions by altering the amount of energy reaching and leaving the ground surface.

$$E = \varepsilon \sigma T^4 \quad (3.0)$$

Where:

E = soil radiation (W/m²); ε = emissivity of soil (typically 0.9-0.95 for most soils); σ = Stefan-Boltzmann constant ($\approx 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$) & T = soil temperature (K)

For the Federal Polytechnic Ede South Campus, the measured radiation and soil-temperature data provide a basis for examining spatial variations in the thermal environment. Variations among sampling points may reflect differences in surface characteristics, soil moisture, vegetation cover, exposure and local land-use conditions. These factors are important because soil temperature is spatially heterogeneous and responds to changes in radiation and surface properties (Li *et al.*, 2024). Therefore, radiation measurements should be interpreted together with soil temperature and other relevant site characteristics rather than as an isolated parameter.

2.4 Creation of a geospatial map

Geospatial mapping provides an effective means of presenting these spatial variations. The measured coordinates and corresponding radiation and temperature values can be imported into GIS software, checked for errors and assigned an appropriate coordinate reference system. The data can then be represented as point features and classified using suitable methods such as natural breaks, quantiles or equal intervals. Thematic maps containing titles, legends, scale bars, north arrows, labels and coordinate grids can subsequently be produced. GIS is increasingly used for environmental monitoring because it supports spatial data integration, visualization, analysis and interpretation (Calka & Szostak, 2025). Consequently, GIS-based radiation and soil-temperature maps helped identify areas of relatively high and low thermal conditions within the study area and provide useful spatial information for environmental assessment and engineering applications.

3. Results and Discussion

3.1 Soil temperature

The underground soil-temperature measurements obtained from the 20 sampling locations at the Federal Polytechnic Ede South Campus (Tables 1 & 2) shows moderate spatial and temporal variability during the seven-day monitoring period. The recorded temperatures ranged from 25.90°C to 31.00°C, with daily ranges of 27.40–29.70°C on Day 1, 28.40–30.30°C on Day 2, 26.50–29.50°C on Day 3, 28.10–30.50°C on Day 4, 28.00–30.59°C on Day 5, 25.90–30.40°C on Day 6, and 28.60–31.00°C on Day 7. The relatively narrow overall range indicates that the subsurface environment maintained comparatively stable thermal conditions despite daily changes.

The observed pattern is consistent with the established behaviour of soils as thermal buffers. Surface temperature variations are progressively damped with depth because soil stores and transfers heat through conduction, while soil water movement can also transport heat vertically. Recent modelling and field observations confirm that subsurface temperature fluctuations are substantially moderated compared with surface conditions and that water movement can influence the propagation of temperature variations through the soil profile (Caprais *et al.*, 2024). Thus, the relatively stable temperatures recorded at South Campus are reasonable for a tropical environment such as Ede.

The differences among sampling locations are likely related to variations in soil moisture, texture, vegetation cover, surface exposure and land use. Soil moisture is particularly important because water strongly influences the thermal behaviour of soil. Recent research demonstrates that soil thermal conductivity varies systematically with water content and soil texture, while differences in saturation and mineral composition can substantially modify heat transfer through soil (Xiong *et al.*, 2023; Sepaskhah & Mazaheri-Tehrani, 2024). The field-scale variability of soil moisture recently reported in southwestern Nigeria further supports the likelihood that spatial differences in moisture conditions contribute to thermal variability within the present study area (Adewole *et al.*, 2024).

The lowest temperature of 25.90°C on Day 6 may therefore reflect increased moisture, cloudiness, rainfall or reduced solar input, whereas the maximum of 31.00°C on Day 7 may be associated with greater solar exposure and relatively drier surface conditions. However, because soil moisture, rainfall and surface radiation were not independently quantified at every sampling point, these factors should be regarded as plausible explanations rather than direct causal relationships. Similarly, the statement that sandy soils necessarily have lower heat storage than clayey soils should be treated cautiously because soil thermal behaviour depends jointly on texture, mineral composition, bulk density and water content rather than texture alone (Xiong *et al.*, 2023).

Table 1. Soil Temperature Results in Centigrade for each Location on the First Day

Location	Coordinates Latitude	Coordinates Longitude	Day 1			Average Value
			Morning	Afternoon	Evening	
1	7°41' 40.94988	4° 24' 49.752	25.1	31.2	28.9	28.4
2	7° 41' 40.99776	4° 24' 48.35988	24.9	28.8	28.5	27.4
3	7°41' 41.18892	4°24' 27.02788	25.7	31.2	29.9	28.9
4	7° 41' 41.2386	4°24' 45.819	25.2	30.3	29.6	28.4
5	7° 41' 38.91588	4°24'50.09904	26.0	30.5	30.1	28.9
6	7° 41' 37.14828	4° 24' 49.5198	25.8	30.0	28.8	28.2
7	7° 41' 37.82904	4° 24' 46.3392	26.5	31.7	29.2	29.1
8	7°43' 35.51364	4° 25' 15.39048	26.9	29.6	30.5	29.0
9	7° 41' 30.61896	4° 24' 49.07916	27.1	30.5	30.0	29.7
10	7° 41' 30.7806	4° 24' 47.655	25.3	29.5	29.8	29.6
11	7° 41' 30.63876	4° 24' 46.51308	26.4	30.7	29.4	28.8
12	7° 41' 30.813	4° 24' 44.97192	27.7	31.1	30.1	29.6
13	7° 41' 27.402	4° 24' 48.39588	27.5	30.7	29.3	29.2
14	7° 41' 27.642848	4° 24' 44.8398	25.5	31.5	29.7	28.9
15	7° 41' 27.59208	4° 24' 46.22184	26.2	30.9	28.3	28.5
16	7° 41' 27.48192	4° 24' 44.94708	27.9	28.1	27.8	27.9
17	7° 41' 23.48232	4° 24' 48.15864	28.0	28.8	30.4	29.1
18	7° 41' 23.58132	4° 24' 46.06884	26.8	30.0	29.1	28.6
19	7° 41' 23.98992	4° 24' 43.43544	27.4	29.8	30.2	29.1
20	7° 41' 24.14976	4° 24' 42.0426	28.1	29.7	30.3	29.4

Table 2. Soil Temperature Results in Centigrade for each Location on the First Day to Seventh Day

Location	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1	28.4	29.5	29.1	30.0	30.1	30.4	30.2
2	27.4	28.4	28.1	28.8	28.7	25.9	29.0
3	28.9	29.4	29.2	29.8	30.4	30.0	30.1
4	28.4	30.1	28.6	28.5	28.9	30.0	29.3
5	28.9	28.9	28.6	29.8	29.6	29.8	30.4
6	28.2	28.2	28.5	29.1	29.3	29.2	29.5
7	29.1	29.1	27.6	29.2	28.7	29.6	29.7
8	29.0	29.5	28.8	29.3	30.1	29.5	30.7
9	29.7	29.3	29.1	30.5	29.2	29.7	31.0
10	29.6	29.1	28.1	29.4	29.4	29.8	30.3
11	28.8	29.6	28.0	28.7	28.0	29.3	29.1
12	29.6	29.5	29.3	29.9	29.9	30.0	30.1
13	29.2	30.3	29.2	29.8	30.2	30.1	30.7
14	28.9	28.4	29.5	29.8	30.5	30.3	30.5
15	28.5	28.1	27.5	28.9	29.2	30.0	28.2
16	27.9	28.7	28.0	28.2	28.6	28.5	28.7

17	29.1	28.8	28.4	29.6	29.1	29.3	29.9
18	28.6	29.5	26.5	28.1	28.6	28.8	28.9
19	29.1	28.7	27.8	29.3	29.1	28.7	29.1
20	29.4	29.8	28.0	29.4	29.2	29.2	28.6

The results are also important from a geotechnical perspective. Soil temperature affects heat transfer and therefore contributes to the thermal regime surrounding buried infrastructure. The observed temperatures do not indicate an extreme thermal environment; consequently, temperature-related effects on shallow foundations are expected to be relatively limited under normal service conditions. Nevertheless, soil temperature should not be considered independently of moisture and other geotechnical properties when assessing foundation performance. Recent work on thermal conductivity for buried infrastructure emphasizes the importance of moisture, mineral composition and soil type in determining heat-transfer behaviour (Kolawole *et al.*, 2024).

For concrete footings, the measured soil-temperature range is generally moderate and is unlikely by itself to produce significant thermal distress. Concrete temperature during curing is controlled by both the environmental temperature and the heat generated by cement hydration. Recent experimental research confirms that curing conditions influence the temperature evolution and hydration behaviour of concrete (Kuryłowicz-Cudowska, 2024). Therefore, the present results suggest that the subsurface thermal environment at South Campus is unlikely to impose severe temperature-related stresses on conventional shallow foundations. However, concrete durability and foundation performance also depend on moisture, concrete mix characteristics, reinforcement, loading, soil bearing capacity and differential settlement; hence, the temperature results should be interpreted as one component of the overall foundation assessment.

3.2 Soil radiation

The soil-radiation measurements also demonstrated spatial and temporal variability across the 20 sampling locations (Table 3). Values ranged from 459.15–475.69 on Day 1, 466.00–479.91 on Day 2, 462.24–475.22 on Day 3, 465.98–481.40 on Day 4, 469.41–480.86 on Day 5, 468.35–479.74 on Day 6, and 469.24–484.09 on Day 7. The gradual increase in the upper values, from 475.69 on Day 1 to 484.09 on Day 7, suggests changing radiation conditions during the monitoring period. However, because the unit and specific measurement principle of the radiation instrument are not stated, the values should be interpreted as instrument-recorded radiation readings rather than directly as solar-energy flux or cumulative heat.

The spatial differences in radiation are consistent with the influence of surface characteristics. Vegetation, shading from buildings and trees, soil colour, moisture, surface roughness and land use can modify the amount of radiant energy reaching and being retained by the ground. Recent research in Nigeria similarly demonstrates that temperature and radiation are important climatic variables affecting soil-water conditions and that their effects vary spatially across landscapes (Okechiet *et al.*, 2024). The present findings therefore reinforce the usefulness of a geospatial approach for identifying localized variations in the thermal environment.

The relationship between radiation and underground temperature is also physically reasonable. Greater radiant input can increase surface heating, after which part of the absorbed energy is transferred into the subsurface. Nevertheless, the relationship is not instantaneous or necessarily linear because soil moisture, thermal conductivity, density and heat capacity control the rate and depth of heat penetration. Recent studies show that water content and soil saturation are major controls on soil thermal conductivity and heat transfer (Xiong *et al.*, 2023; Liu *et al.*, 2024). Consequently, locations with similar radiation readings may still exhibit different underground temperatures because of differences in soil moisture and composition.

Overall, the soil-temperature and radiation results indicate a moderately variable but generally stable subsurface thermal environment at Federal Polytechnic Ede (South Campus). The findings agree with recent studies showing that soil thermal behaviour is governed by the interaction of radiation, moisture, texture and other physical properties rather than by a single environmental variable (Adewole *et al.*, 2024; Sepaskhah & Mazaheri-Tehrani, 2024). The relatively moderate temperature range is favourable for ordinary shallow-foundation applications, while the observed spatial variations emphasize the importance of incorporating local soil conditions into geotechnical and thermal assessments. For future studies, simultaneous measurement of soil moisture, thermal conductivity, thermal diffusivity, bulk density, depth and meteorological variables would provide a stronger quantitative basis for establishing the relationships between radiation, soil temperature and foundation behaviour.

Table 3. Soil Radiation Results for each Location on the First Day to Seventh Day

Location	Radiation (w /m ² k ⁴)						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1	468.16	474.77	472.59	477.97	478.50	481.05	479.17
2	459.15	468.00	466.48	470.67	470.03	475.33	471.45
3	471.39	476.50	473.16	476.58	480.86	477.83	478.73

4	471.19	479.12	473.16	468.84	471.09	478.17	473.21
5	470.93	471.30	469.17	476.73	475.61	476.64	480.50
6	466.76	466.55	468.50	472.60	473.39	472.76	474.59
7	472.62	472.34	462.86	473.22	470.60	475.45	476.52
8	471.71	474.78	471.91	476.07	478.18	475.20	483.10
9	472.96	473.53	472.62	481.40	474.04	476.10	484.09
10	466.79	472.54	466.89	474.67	474.05	476.54	479.65
11	470.70	475.64	465.54	470.07	470.23	473.75	472.33
12	475.67	474.78	473.40	477.55	477.15	477.77	478.87
3	472.74	479.91	473.32	476.88	479.49	478.44	482.69
14	471.54	467.83	475.22	479.05	481.17	479.74	481.26
15	468.43	466.00	462.24	470.87	472.79	471.52	466.96
16	465.01	470.14	465.29	470.24	469.36	468.35	470.06
17	470.09	469.81	468.27	475.26	472.57	473.40	477.38
18	469.33	474.99	456.33	465.98	469.44	470.25	471.04
19	472.52	470.15	464.13	473.83	472.15	469.68	472.59
20	473.96	476.74	465.30	473.95	472.92	473.14	469.24

3.3 Soil radiation intensity and implications for concrete foundation footings

The calculated soil radiation intensity at the Federal Polytechnic Ede (South Campus) exhibited clear spatial and diurnal variations, reflecting changes in soil temperature, surface energy exchange and soil characteristics. The morning values ranged from approximately 451.40 to 463.50 W/m², with the dominant class of 457.45–459.47 W/m² covering about 3,689.91 m² (Fig. 1). The relatively low morning values are associated with overnight cooling and the gradual increase in solar energy input after sunrise. In contrast, afternoon values increased to approximately 478.50–497.00 W/m², with the dominant class of 484.67–487.75 W/m² occupying about 3,082.08 m² (Fig. 2). Evening values declined to 465.90–479.50 W/m², although they remained above the morning range because heat stored in the soil continued to be released after the period of maximum solar heating (Fig. 3).

This diurnal pattern is consistent with the physical relationship between soil temperature and outgoing long-wave radiation described by the Stefan–Boltzmann law. Recent research confirms that ground-surface temperature and radiative energy exchange vary substantially throughout the day, with surface conditions controlling the transfer of heat between the land and atmosphere (Wang *et al.*, 2024). Similarly, Sanford *et al.* (2024) reported that substantial diurnal temperature variations occur in surface soils and are particularly pronounced in shallow soil layers. More recently, Chen *et al.* (2026) demonstrated that the daily temperature signal propagates downward into the soil as a thermal wave, with its amplitude decreasing with depth. Thus, the higher afternoon radiation observed in the present study is consistent with the expected response of soil surfaces to stronger daytime heating.

The predominantly sandy nature of the study-area soils provides a plausible explanation for the relatively rapid heating and cooling observed. Sandy soils generally have greater pore spaces and lower water-holding capacity than fine-textured soils, allowing their thermal response to change rapidly with atmospheric forcing. The recent review by Wu *et al.* (2025) shows that soil thermal conductivity is strongly influenced by water content, degree of saturation, dry bulk density, porosity and mineral composition. Consequently, spatial variations in texture and moisture content can produce differences in thermal response even under similar atmospheric conditions.

The radiation results also have implications for foundation engineering. In the short term, the observed thermal fluctuations may cause small temperature-induced expansion and contraction of concrete and minor changes in the soil–concrete interface. However, the measured values are not sufficiently extreme to indicate an immediate risk of thermal damage to properly designed concrete footings. The more important consideration is the interaction between temperature and soil moisture. Repeated heating may increase evaporation and produce local moisture variations, particularly in exposed sandy or clay-bearing zones. Such changes can modify the thermal and mechanical behaviour of the supporting soil. Therefore, foundation performance should be assessed in conjunction with moisture conditions, soil classification, drainage and bearing characteristics rather than radiation intensity alone.

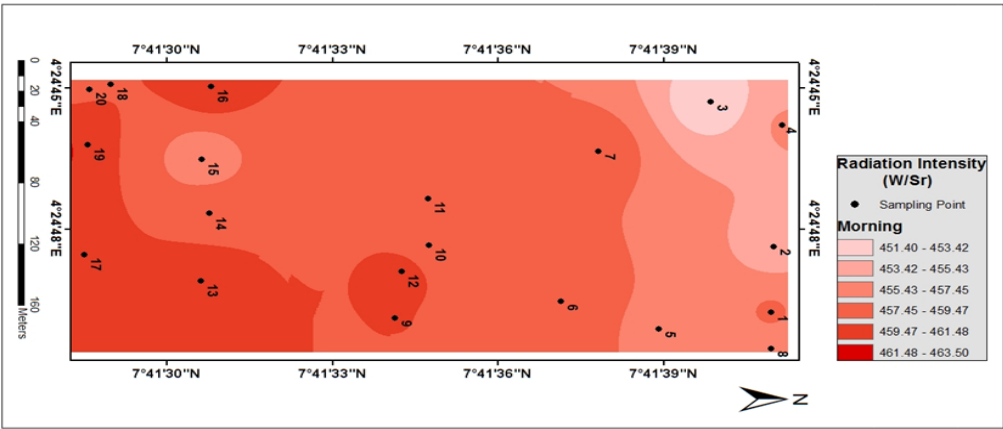


Fig. 1. Radiation Variation across Sampling Locations in the Morning Period

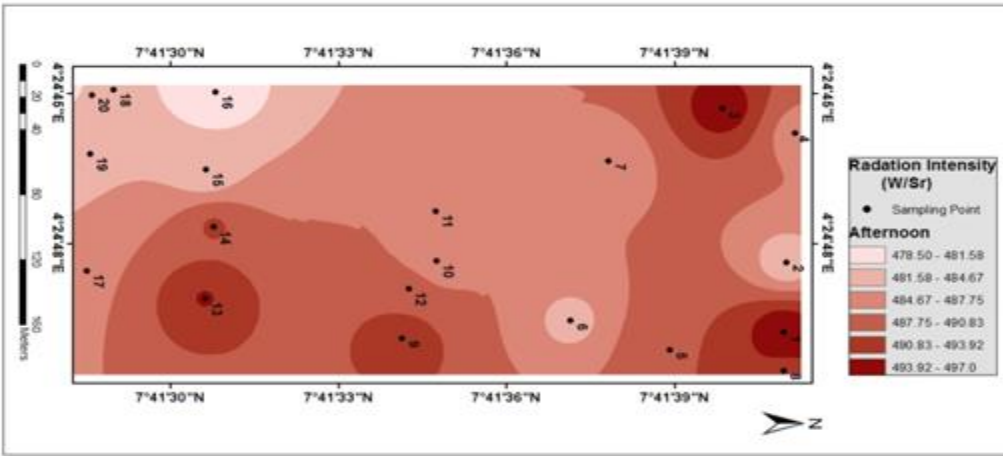


Fig. 2. Radiation Variation across Sampling Locations in the Afternoon Period

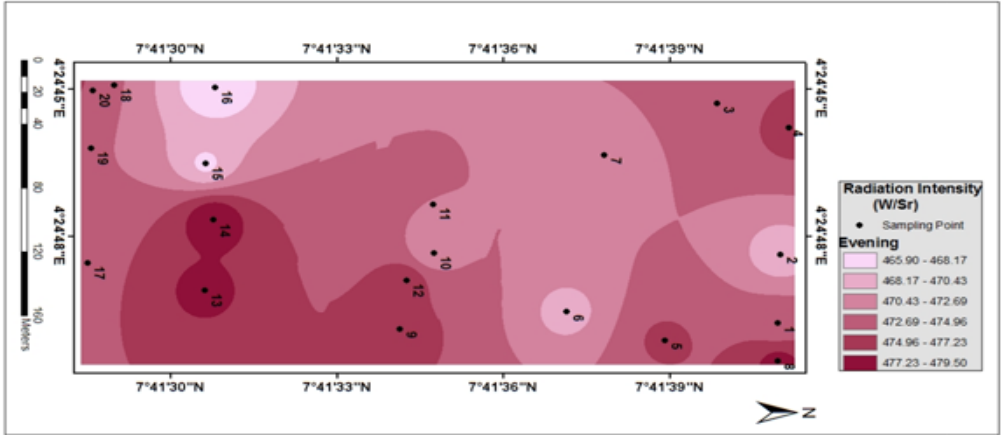


Fig. 3. Radiation Variation across Sampling Locations in the Evening Period

Over the long term, repeated thermal cycles may contribute to cumulative thermal stresses in concrete, while persistent changes in soil moisture can influence settlement and soil–foundation interaction. These effects are likely to be gradual rather than catastrophic under the radiation conditions recorded at the study site. The significance of diurnal thermal variation is supported by Sanford *et al.* (2024), who showed that temperature fluctuations are important characteristics of shallow soils, while Chen *et al.* (2026) demonstrated that diurnal thermal signals progressively attenuate with depth. Therefore, foundations located deeper below the ground surface may experience substantially smaller temperature fluctuations than those occurring at the soil surface.

Overall, the results demonstrate that soil radiation at the Federal Polytechnic Ede (South Campus) varies systematically from morning through afternoon to evening, with the highest values (39.8°C) occurring during the

afternoon and the lowest (23.6°C) generally occurring during the morning. The spatial variation is controlled by the combined effects of soil temperature, texture, moisture and surface energy exchange. The findings agree with recent studies showing that soil thermal behaviour is strongly controlled by diurnal energy input and soil physical properties. The results further indicate that the measured radiation regime is unlikely to cause immediate structural problems in properly designed foundations, although long-term monitoring of soil moisture, temperature and foundation movement would be beneficial, particularly where buildings are founded on heterogeneous soils. Integrating geospatial soil-temperature mapping with thermal and geotechnical data therefore provides a useful basis for foundation assessment and environmental management at the study site.

4. Conclusion

The study established the spatial and temporal variability of underground soil temperature and associated thermal characteristics at the South Campus of Federal Polytechnic Ede, Osun State, using field measurements, laboratory soil characterization, radiation assessment, and GIS-based spatial analysis. Sandy loam was the predominant soil texture, although localized variations in sand, silt, and clay contents indicate spatial differences in soil-forming and depositional conditions. Such textural variability is important because particle-size distribution, bulk density, porosity, and moisture content influence soil heat transfer and thermal behavior (Wu *et al.*, 2025).

Soil temperature varied spatially and temporally, with generally higher afternoon values than morning and evening measurements, reflecting the influence of solar heating. The observed thermal variability was also associated with soil texture, vegetation, and moisture conditions. Sandy locations exhibited comparatively rapid heating and cooling, whereas finer-textured areas showed greater thermal stability, consistent with the established influence of water content and soil texture on thermal properties (Renet *al.*, 2024; Wu *et al.*, 2025). Recent research in southwestern Nigeria similarly demonstrates substantial spatial variability in soil moisture and temperature associated with soil and land-cover conditions (Adewole *et al.*, 2024).

The GIS outputs effectively identified areas of relatively high and low thermal conditions and demonstrated the usefulness of spatial mapping for subsurface characterization. However, the results should be regarded as a baseline because thermal conductivity, diffusivity, and specific heat were not directly measured.

Future investigations should extend monitoring across wet and dry seasons, incorporate simultaneous soil-moisture measurements, directly determine major thermal properties, increase sampling density, and integrate GIS with geophysical techniques such as electrical resistivity tomography and ground-penetrating radar. These improvements would enhance the reliability of thermal models and their application to geotechnical, environmental, agricultural, and infrastructure planning.

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