

MAPPING LAND SURFACE EMISSIVITY PATTERNS IN A COASTAL WETLAND ENVIRONMENT; A GIS-BASED STUDY OF BAYELSA STATE, NIGERIA

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ABSTRACT

Land surface emissivity (LSE) is an important surface parameter influencing long-wave radiation exchange and the retrieval of land surface temperature from satellite data. In many studies within the Niger Delta, emissivity is commonly treated as spatially uniform, despite the region's pronounced land-cover heterogeneity. This study examines the spatial distribution of land surface emissivity in Bayelsa State, Nigeria, using satellite remote sensing and Geographic Information System (GIS) techniques. The analysis was based on Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) imagery acquired in 2020, with a spatial resolution of 30 m for reflective bands and 100 m (resampled to 30 m) for thermal bands. Land surface emissivity was estimated using an NDVI-based emissivity retrieval approach, following established procedures in thermal remote sensing, and the resulting emissivity values were analysed spatially within a GIS environment. The results indicate clear spatial variability in emissivity across Bayelsa State. Very high to high emissivity values (≥ 0.96) dominate wetlands, mangrove forests, and riverine environments, accounting for approximately 65% of the study area, while low to very low emissivity values (≤ 0.93) are primarily associated with urbanised and exposed surfaces, representing about 17% of the area. These patterns reflect differences in land cover, surface material properties, and moisture conditions rather than statistically inferred causal relationships. While the observed spatial trends are consistent with patterns reported in previous studies of coastal and wetland environments, this study does not attempt inferential validation. Instead, it provides a baseline, spatially explicit depiction of land surface emissivity in Bayelsa State. The findings highlight the importance of treating emissivity as a spatially variable parameter in environmental analyses and offer foundational information to support future climate-related and land-use studies in the Niger Delta.

Keywords: Land Surface Emissivity; Landsat 8 OLI/TIRS; Remote Sensing; Geographic Information System (GIS); Spatial Variability; Coastal Wetland Environment

1. INTRODUCTION

Land surface emissivity (LSE) is a fundamental surface property that governs the efficiency with which the Earth's surface emits long-wave radiation and, by extension, regulates surface-atmosphere energy exchange processes. Within the framework of surface energy balance theory, emissivity constitutes a critical parameter influencing outgoing long-wave radiation, land surface temperature retrieval, and the partitioning of energy between sensible and latent heat fluxes (Li et al., 2020). Accurate representation of emissivity is therefore essential for physically meaningful interpretation of satellite-derived thermal observations.

From a theoretical perspective, surface energy balance models conceptualise the land surface as an interface where net radiation is partitioned into turbulent and ground heat fluxes. In this context, emissivity directly affects the magnitude of long-wave radiation emitted from the surface and influences estimates of surface temperature and energy fluxes. Consequently, assumptions regarding emissivity behaviour have direct implications for the reliability of remote sensing-based environmental analyses. Treating emissivity as spatially uniform contradicts the physical reality that surface radiative properties vary with material composition, vegetation structure, moisture availability, and land-use characteristics.

Bayelsa State, located within the core of the Niger Delta, presents a particularly compelling case for examining land surface emissivity variability. The state is dominated by an extensive coastal wetland system comprising mangrove forests, freshwater and brackish wetlands, tidal creeks, river networks, and floodplains, alongside rapidly expanding urban and peri-urban settlements. These contrasting surface environments exhibit markedly different physical and thermal properties. Dense mangrove vegetation and persistently saturated wetlands are expected to display high emissivity values due to their moisture-rich and organic surface composition, whereas built-up areas, exposed soils, and infrastructure corridors are likely to exhibit lower emissivity associated with impervious materials and reduced surface moisture.

Despite the environmental complexity of Bayelsa State, most remote sensing-based environmental studies conducted in the Niger Delta have prioritised land surface temperature mapping, land-cover change detection, or general environmental monitoring, often relying on fixed or literature-derived emissivity values. While such approaches may be methodologically expedient, they obscure the extent to which emissivity itself varies spatially across the landscape and limit the physical interpretability of thermal observations. As a result, the surface energy dynamics of coastal wetland environments remain insufficiently characterised at the local scale.

The research gap addressed in this study is therefore not merely the absence of emissivity studies in Bayelsa State, but the lack of spatially explicit, empirically derived emissivity information capable of capturing the heterogeneity of a coastal wetland landscape. Without such baseline spatial analysis, subsequent environmental, hydrological, or climate-oriented studies risk relying on oversimplified surface assumptions. This study responds to that gap by applying satellite remote sensing and GIS techniques to map and interpret the spatial variability of land surface emissivity across Bayelsa State. By grounding the analysis within surface energy balance theory and focusing on spatial patterns rather than inferential modelling, the study provides a scientifically coherent and contextually relevant foundation for improved environmental analysis in the Niger Delta.

2. STATEMENT OF THE PROBLEM

Land surface emissivity (LSE) is a critical parameter in land surface temperature estimation and surface energy balance studies, yet it is frequently treated as a spatially constant variable in environmental research conducted within Nigeria. Several land surface temperature and thermal remote sensing studies in the Niger Delta region have relied on fixed or literature-based emissivity values rather than spatially derived estimates, largely due to data limitations or methodological simplifications (Ayanlade et al., 2021). While such approaches may be adequate for broad-scale assessments, they are potentially problematic in regions characterised by pronounced land-cover heterogeneity.

The Niger Delta, and Bayelsa State in particular, exhibits a complex mosaic of wetlands, mangrove forests, open water bodies, agricultural land, exposed soil, and rapidly expanding urban areas. Each of these surface types possesses distinct material properties and moisture conditions that influence emissivity behaviour. Empirical studies conducted in similar coastal and wetland environments have demonstrated that emissivity varies substantially across land-cover classes, with vegetated and moisture-rich surfaces exhibiting higher values than urban and bare surfaces (Ogashawara & Bastos, 2022; Sekertekin & Bonafoni, 2023). However, spatially explicit emissivity assessments specific to Bayelsa State remain scarce, and existing Nigerian studies rarely quantify how emissivity variability manifests across local landscapes.

The continued application of constant emissivity assumptions in such a heterogeneous environment risks masking important spatial variations in surface radiative properties. This limitation does not necessarily invalidate previous studies but constrains their capacity to represent local-scale surface energy processes accurately. Before emissivity information can be meaningfully integrated into climate adaptation or environmental planning frameworks, there is a need for intermediary spatial analyses that document how emissivity varies across different land-cover types within the region.

Accordingly, the problem addressed in this study is not the direct evaluation of climate impacts or adaptation outcomes, but rather the absence of baseline, spatially explicit information on land surface emissivity in Bayelsa State. By providing a descriptive spatial assessment of emissivity patterns, this study establishes an empirical foundation upon which more advanced climate-oriented analyses and adaptation studies may subsequently build.

3. AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to map and describe the spatial distribution of land surface emissivity (LSE) in Bayelsa State, Nigeria, using satellite remote sensing and Geographic Information System (GIS) techniques. The study focuses on documenting spatial patterns and providing a baseline dataset to support future environmental and climate-related analyses. The specific objectives are to:

1. Generate a spatially explicit land surface emissivity map of Bayelsa State.
2. Characterise the spatial variability of land surface emissivity across different environmental settings.
3. Describe associations between emissivity patterns and dominant land-cover types .

4. Provide baseline information on emissivity patterns

4. RESEARCH QUESTIONS

1. What is the spatial distribution of land surface emissivity across Bayelsa State?
2. How does land surface emissivity vary across different environmental settings?
3. What associations can be observed between emissivity patterns and dominant land-cover types within Bayelsa State?
4. How can the spatially explicit information on emissivity serve as a baseline for future environmental monitoring and land-use planning in the region?

5. RESEARCH PROPOSITIONS

Proposition 1: Land surface emissivity in Bayelsa State is spatially heterogeneous, with variation observable across different environmental settings such as wetlands, mangroves, water bodies, and urban areas.

Proposition 2: Land surface emissivity shows observable spatial patterns associated with dominant land-cover types, where vegetated and moisture-rich surfaces exhibit higher emissivity than urbanised or exposed surfaces.

6. LITERATURE REVIEW

Land surface emissivity (LSE) is a key parameter in surface energy balance and thermal remote sensing, controlling the efficiency with which terrestrial surfaces emit long-wave radiation. Accurate estimation of LSE is crucial for reliable land surface temperature retrieval and for understanding surface–atmosphere energy interactions (Li et al., 2020). Despite its importance, many studies in Nigeria and the broader sub-Saharan region have traditionally assumed constant emissivity values, largely due to limitations in data availability or computational resources (Ayanlade et al., 2021). This assumption, while simplifying analysis, obscures significant spatial variability driven by heterogeneous land cover, surface moisture, and anthropogenic modification.

Recent advances in satellite remote sensing, particularly from sensors such as Landsat 8 OLI/TIRS, MODIS, and Sentinel-2, have enabled more accurate emissivity mapping. Ermida et al. (2021) demonstrated that including land-cover heterogeneity in emissivity retrieval improves the physical realism of surface temperature products. Similarly, Ogashawara and Bastos (2022) highlighted that coastal and wetland ecosystems exhibit consistently higher emissivity due to dense vegetation and moisture-rich substrates, while urban and bare surfaces show lower emissivity owing to impervious materials. Sekertekin and Bonafoni (2023) also emphasised that urbanisation and construction materials introduce systematic reductions in surface emissivity, with implications for local thermal behaviour.

While these studies provide valuable insights, research specifically focused on the Niger Delta and Nigerian coastal wetlands remains limited. Most Nigerian studies have concentrated on land surface temperature, hydrological assessments, or vegetation monitoring, often without spatially explicit emissivity mapping. Consequently, the spatial heterogeneity of emissivity in highly

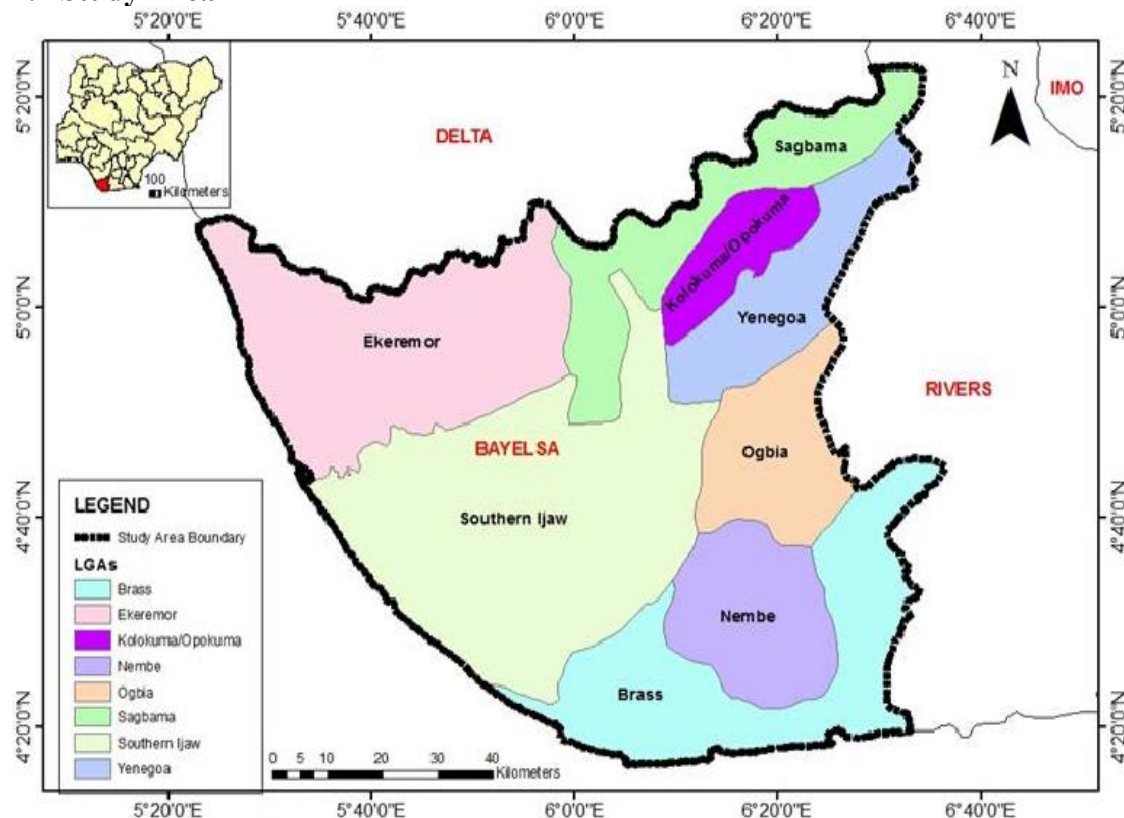
complex landscapes such as Bayelsa State remains poorly understood. For example, Ayanlade et al. (2021) noted that fixed emissivity assumptions may underestimate thermal contrasts in wetland versus urbanised areas, but did not provide empirical emissivity maps for verification.

Critically, the existing literature shows two important gaps: (1) a lack of descriptive, spatially explicit emissivity datasets for Nigerian coastal wetlands, and (2) limited contextualisation of how land cover and surface moisture influence emissivity patterns in these environments. While international studies provide methodological guidance and comparative benchmarks, they often do not account for the unique environmental characteristics of the Niger Delta, including its extensive mangrove forests, tidal wetlands, and rapidly expanding urban settlements.

This study addresses these gaps by providing a spatially explicit assessment of land surface emissivity in Bayelsa State, integrating remote sensing and GIS techniques. Unlike prior Nigerian studies, it explicitly characterises emissivity patterns across multiple land-cover types and environmental settings, offering a baseline dataset for the region. By situating the analysis within the surface energy balance framework, the study not only extends understanding of spatial emissivity variability in Nigerian wetlands but also provides a scientifically coherent foundation for future environmental monitoring, land-use planning, and potential climate studies.

7. METHODOLOGY

7.1 Study Area



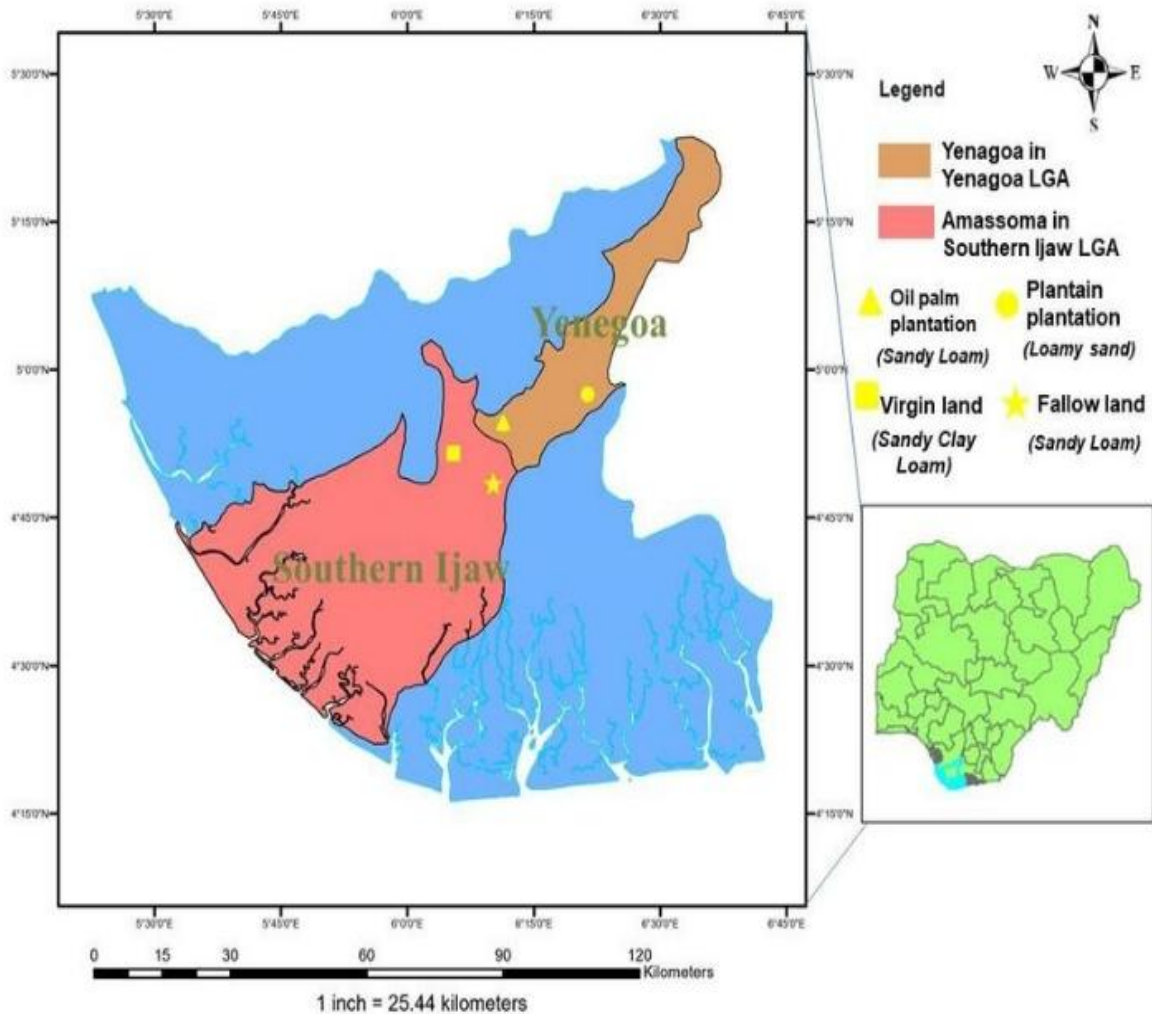
Source: Bayelsa State map with administrative boundaries — from a GIS analysis of flood vulnerability (Berezi & Nwankwoala, 2023).

Bayelsa State, located in the core of the Niger Delta, southern Nigeria, is characterised by extensive wetlands, mangrove forests, tidal creeks, rivers, and rapidly urbanising settlements. The area lies between latitudes 4°58' N and 5°10' N and longitudes 6°52' E and 7°05' E. Its humid tropical climate, dense vegetation cover, and water-saturated soils make it a highly heterogeneous environment, suitable for examining spatial variation in land surface emissivity.

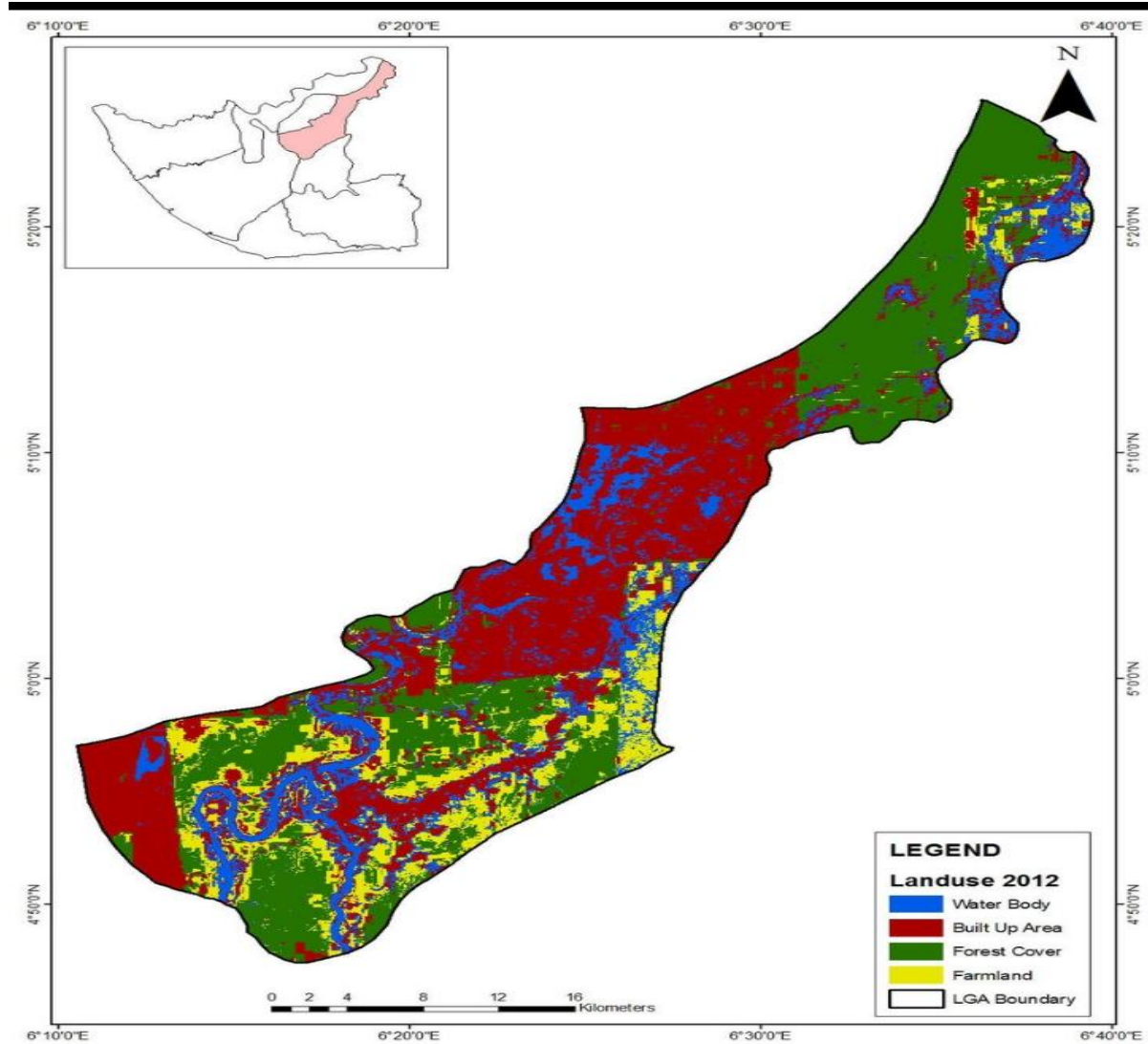
7.2 Data Acquisition

The study utilised Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) satellite imagery acquired on 15 February 2020. The choice of Landsat 8 was motivated by its thermal band capabilities and sufficient spatial resolution for regional environmental analysis. The reflective bands were acquired at 30 m spatial resolution, while the thermal infrared bands have a native resolution of 100 m, resampled to 30 m to match the reflective bands and facilitate GIS analysis.

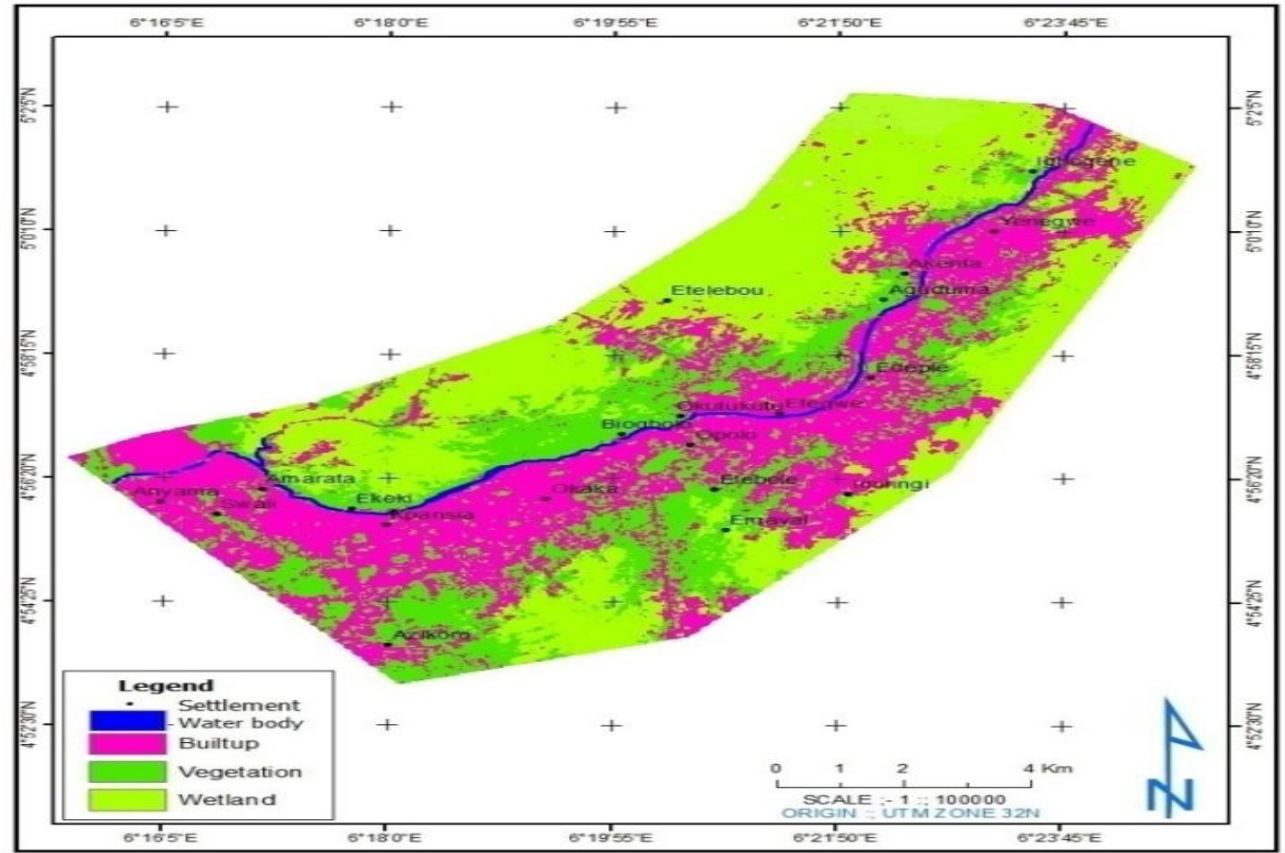
Ancillary data including maps depicting land-cover types such as water bodies, mangroves, vegetation, and built-up areas (Agbai & Kosuwei, 2022; Berezi & Nwankwoala, 2023; Hanachor & Week, 2014; Elemuwa, Lawrence & Wali, 2021), was used to support the visual interpretation of satellite-derived emissivity patterns in relation to specific land-cover classes. .



Source: Bayelsa State land-use map showing local government areas and land-use types — from research on soil properties in Yenagoa and Amassoma communities (Agbai & Kosuwei, 2022).



Source: Hanachor, C. H. & Week, D. A. (2014). Geospatial Mapping and Analysis of Nigeria Flood Disaster in Yenagoa. Geospatial research.



Source: Elemuwa, C., Lawrence, H., & Wali, E. (2021). Spatio-Temporal Changes of LULC in Yenagoa Urban Area using Landsat imagery. *Journal of Geography, Environment and Earth Science International*.

7.3 Pre-processing

Satellite imagery was pre-processed to ensure reliability and comparability. The steps included:

1. Radiometric Calibration: Conversion of digital numbers (DN) to top-of-atmosphere (TOA) radiance using standard Landsat 8 calibration coefficients.
2. Atmospheric Correction: Correction of atmospheric effects (e.g., scattering, absorption) was performed using the Dark Object Subtraction (DOS) method, ensuring that surface reflectance values accurately represent ground conditions.
3. Cloud Masking: Cloud-affected pixels were masked using the Fmask algorithm to prevent contamination of emissivity values.

7.4 Emissivity Retrieval

Land surface emissivity was estimated using the NDVI-based method, a widely accepted approach for heterogeneous surfaces. The procedure involved:

1. Calculating the Normalized Difference Vegetation Index (NDVI) using Landsat 8 OLI bands 4 (Red) and 5 (Near-Infrared).
2. Determining proportion of vegetation cover (P_v) for each pixel.
3. Estimating emissivity (ε) using the formula:

$$\varepsilon = \varepsilon_v \cdot P_v + \varepsilon_s \cdot (1 - P_v) + C$$

Where:

ε_v = 0.99 (emissivity of vegetation)

ε_s = 0.97 (emissivity of soil/bare surface)

P_v = Proportion of vegetation cover

C = 0.005 (Surface roughness correction coefficient)

This method allows spatially explicit estimation of emissivity while accounting for land-cover heterogeneity, making it suitable for wetlands, mangroves, urban, and agricultural areas present in Bayelsa State.

7.5 Spatial Analysis and Interpretation

The derived emissivity raster was imported into ArcGIS 10.8 for spatial analysis. Procedures included:

1. Classification: Emissivity values were classified into five classes — Very Low (≤ 0.91), Low (0.92–0.93), Moderate (0.94–0.95), High (0.96–0.97), Very High (≥ 0.98) — based on established thresholds in the literature (Ogashawara & Bastos, 2022).
2. Overlay Analysis: Emissivity classes were overlaid with land-cover maps to describe spatial associations.
3. Visual Interpretation: Spatial patterns were interpreted to identify areas of high, moderate, and low emissivity in relation to environmental settings (wetlands, mangroves, urban areas).

7.6 Validation and Reliability

Although the study is primarily descriptive and spatial, several measures ensured the reliability of results:

Cross-check with land-cover map: Areas classified as wetlands, mangroves, or urban were visually compared with the corresponding emissivity classes.

Comparison with published values: Retrieved emissivity ranges were compared with literature-reported emissivity values for tropical wetlands and coastal environments (Ogashawara & Bastos, 2022; Sekertekin & Bonafoni, 2023).

Consistency check: Pixels with anomalous emissivity values were manually inspected and, where necessary, corrected or masked.

These steps ensure the results are replicable, transparent, and reliable while remaining within the scope of a GIS-based descriptive study.

8. RESULTS AND DISCUSSION

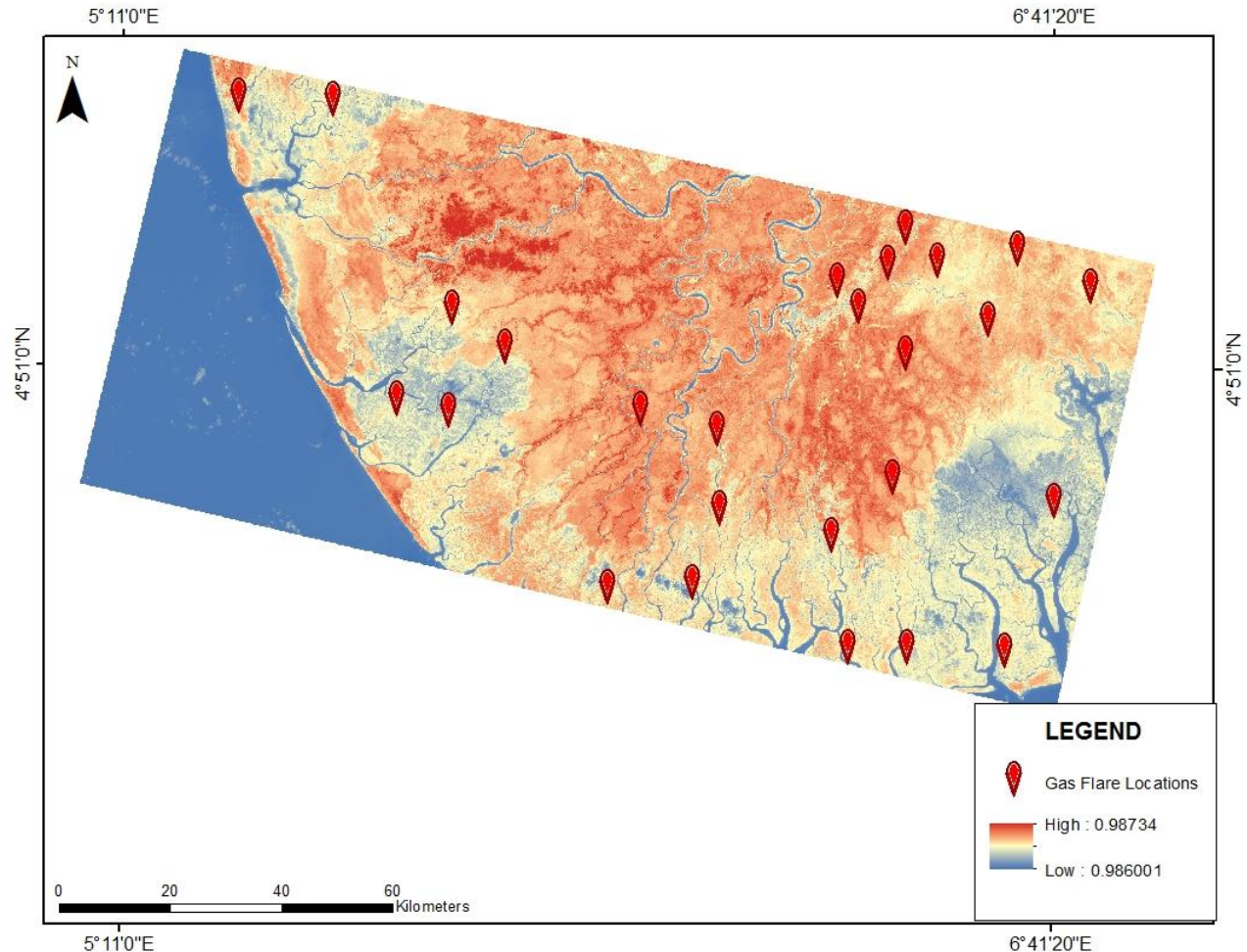


Fig 8.1: Bayelsa State Land Surface Emissivity

Source: (Author Analysis, 2020)

The land surface emissivity has to do with the energy tied up in the behavior of the molecules that form the surface; this implies that as temperature increases, emissivity also increases because substances emit radiations with an intensity proportional to a temperature from the images as shown in figure 8.1. Land surface emissivity for Bayelsa State is generally high across the study area though with pockets of low emissivity in the south-south west and south-south east region of the study area with a predominance of water bodies and estuaries discharging waters to the ocean.

Table 1: Spatial Distribution of Land Surface Emissivity Classes in Bayelsa State

Emissivity Class	Approximate LSE Range	Dominant Land Cover Characteristics	Areal Coverage (%)	Spatial Description (Based on Map)
Very High Emissivity	≥ 0.98	Dense mangrove vegetation, wetlands, water bodies	38%	Concentrated in southern and central coastal zones, riverine and swamp forest areas
High Emissivity	0.96 – 0.97	Moist vegetation, agricultural land, riparian zones	27%	Widely distributed across inland vegetated regions
Moderate Emissivity	0.94 – 0.95	Mixed land cover, sparse vegetation	18%	Transitional zones between wetlands and settlements
Low Emissivity	0.92 – 0.93	Built-up areas, exposed soil surfaces	12%	Urban and peri-urban centres such as Yenagoa and surrounding settlements
Very Low Emissivity	≤ 0.91	Bare surfaces, infrastructure corridors	5%	Isolated patches mainly within highly developed areas
Total	—	—	100%	—

The Very High and High emissivity classes jointly account for about 65% of Bayelsa State, reflecting the dominance of wetlands, mangroves, and moist vegetated surfaces, as clearly shown on the emissivity map.

Low to Very Low emissivity areas (17%) correspond spatially with urbanised and anthropogenically modified zones, which appear as distinct patches on the map.

The Moderate emissivity class (18%) represents ecotonal and mixed-use landscapes, forming buffers between wetlands and built-up areas.

8.1 Spatial Distribution of Land Surface Emissivity in Relation to Existing Studies

The spatial distribution of land surface emissivity (LSE) across Bayelsa State exhibits pronounced heterogeneity, with emissivity values forming coherent spatial patterns rather than random dispersion. High to very high emissivity classes dominate large portions of the study area, particularly within coastal wetlands, mangrove forests, and riverine floodplains. This finding aligns closely with international studies conducted in coastal and wetland environments,

which consistently report elevated emissivity values for densely vegetated and moisture-rich surfaces (Ogashawara & Bastos, 2022; Sekertekin & Bonafoni, 2023).

The dominance of high emissivity values observed in Bayelsa State corroborates the theoretical expectation that organic soils, saturated substrates, and dense vegetation enhance long-wave radiation emission efficiency. However, unlike many global-scale studies that generalise wetland emissivity behaviour, the present results demonstrate how these patterns manifest spatially within a highly fragmented Niger Delta landscape. The mapped distribution reveals subtle intra-wetland variability, suggesting that emissivity within wetlands is not entirely uniform but responds to local differences in vegetation density and hydrological conditions. This spatial nuance is rarely captured in Nigerian studies, which often adopt fixed emissivity values for broad land-cover classes.

8.2 Emissivity Variation Across Environmental Settings: Comparison with Literature

Marked variation in emissivity is evident across distinct environmental settings within Bayelsa State. Mangrove forests and freshwater wetlands consistently exhibit the highest emissivity values, a result that aligns with findings from coastal wetland studies in Asia and South America, where similar ecosystems have been shown to maintain emissivity values exceeding 0.96 (Ermida et al., 2021). Open water bodies also display high emissivity, though their spatial extent is comparatively limited and fragmented.

Urban areas and zones of exposed soil or infrastructure exhibit moderate to low emissivity values. This pattern is consistent with urban remote sensing studies that associate impervious surfaces and construction materials with reduced emissivity due to their physical composition and lower moisture content (Sekertekin & Bonafoni, 2023). The present findings therefore reinforce the broader consensus in the literature regarding the relationship between surface materials and emissivity behaviour.

However, a notable contrast emerges when compared with some Nigerian land surface temperature studies that implicitly assume emissivity uniformity across urban and peri-urban environments. The spatial patterns observed in Bayelsa State indicate that even within urban areas, emissivity varies depending on surface modification intensity and proximity to vegetated or water-logged zones. This highlights a limitation in earlier Nigerian studies and underscores the added value of spatially explicit emissivity mapping.

8.3 Associations Between Emissivity and Land Cover in a Niger Delta Context

Spatial overlay analysis reveals clear associations between emissivity patterns and dominant land-cover types. Areas classified as mangrove forest and wetland correspond predominantly to high and very high emissivity classes, while built-up and sparsely vegetated areas align with lower emissivity values. These associations are consistent with established relationships reported in the literature, which attribute higher emissivity to vegetated and moisture-rich surfaces (Li et al., 2020).

Nevertheless, the present results extend existing knowledge by demonstrating that these associations are not spatially homogeneous across the landscape. Transitional zones, particularly at the interface between wetlands and expanding urban areas, exhibit mixed emissivity signatures. This spatial complexity contrasts with the simplified land-cover–emissivity

relationships often reported in global or continental-scale studies and reflects the dynamic land-use changes occurring in the Niger Delta.

By situating these associations within a local context, the study provides empirical support for arguments made by Ayanlade et al. (2021), who suggested that fixed emissivity assumptions may inadequately represent heterogeneous Nigerian environments. The results thus move beyond descriptive repetition by showing how known theoretical relationships are spatially expressed in Bayelsa State.

8.4 Contribution of the Results to Existing Knowledge

While the findings broadly align with international emissivity research, the principal contribution of this study lies in its regional specificity. Unlike many prior Nigerian studies that focus on land surface temperature without explicitly mapping emissivity, this study provides a spatially resolved emissivity dataset for a coastal wetland system. In doing so, it bridges a critical gap between global emissivity literature and local environmental conditions in the Niger Delta.

Rather than challenging established emissivity theory, the results refine and contextualise existing knowledge, demonstrating that the physical principles reported in the literature remain valid but require spatially explicit representation in heterogeneous landscapes. The study therefore advances the literature by translating generalised emissivity concepts into a locally grounded spatial framework.

Overall, the results are consistent with the broader body of emissivity literature, particularly regarding the influence of vegetation, moisture, and surface materials on emissivity values. However, by revealing fine-scale spatial variability within wetlands and urban–wetland transition zones, the study adds depth to existing understanding and highlights the limitations of uniform emissivity assumptions in Nigerian environmental research.

9. INTERPRETATION OF RESEARCH PROPOSITIONS

Given the descriptive and spatial nature of this study, formal hypothesis testing and null hypothesis rejection are not applicable. The analysis does not employ inferential statistics or probabilistic testing; therefore, conclusions cannot be drawn in terms of statistical acceptance or rejection. Instead, the study evaluates research propositions through systematic spatial interpretation of mapped emissivity patterns, consistent with established practices in exploratory remote sensing and GIS-based environmental analysis.

9.1 Interpretation of Proposition 1

Proposition 1: Land surface emissivity in Bayelsa State is spatially heterogeneous, with variation observable across different environmental settings such as wetlands, mangroves, water bodies, and urban areas.

The spatial distribution of land surface emissivity across Bayelsa State demonstrates clear heterogeneity. Distinct emissivity zones are evident across the landscape, with high and very high emissivity values concentrated in wetlands, mangrove forests, and riverine environments, and lower values associated with urbanised and exposed surfaces. This variation is spatially

coherent and aligns with known differences in surface moisture, vegetation density, and material composition.

Rather than constituting statistical proof, these observations provide empirical spatial evidence that emissivity varies meaningfully across environmental settings within the study area. The proposition is therefore supported through spatial pattern recognition and physical interpretation, not through inferential validation. This approach is appropriate given the study's reliance on satellite-derived emissivity mapping and GIS analysis.

9.2 Interpretation of Proposition 2

Proposition 2: Land surface emissivity shows observable spatial patterns associated with dominant land-cover types, where vegetated and moisture-rich surfaces exhibit higher emissivity than urbanised or exposed surfaces.

Overlay analysis between emissivity classes and land-cover categories reveals consistent spatial correspondence. Vegetated and moisture-rich land-cover types—particularly mangroves and freshwater wetlands—are predominantly associated with high emissivity values, while built-up areas and exposed soils correspond to moderate or low emissivity classes. These associations reflect established physical relationships between surface properties and emissivity behaviour documented in the literature.

Importantly, these findings are interpreted as spatial associations rather than causal relationships. The study does not claim that land cover statistically determines emissivity, but rather that emissivity patterns co-occur with land-cover types in a manner that is physically consistent and spatially interpretable. This form of interpretation is standard in descriptive remote sensing studies and avoids the methodological misuse of hypothesis rejection.

METHODOLOGICAL JUSTIFICATION AND SCIENTIFIC VALIDITY

The replacement of null hypothesis testing with research propositions enhances the scientific integrity of the study. Visual correspondence between mapped variables, when combined with physical reasoning and literature support, constitutes valid evidence in exploratory spatial analysis. However, such evidence cannot and should not be framed as statistical hypothesis rejection.

By interpreting propositions through spatial evidence, the study maintains methodological honesty, aligns conclusions with analytical capacity, and avoids overstatement. The propositions function as conceptual guides that structure interpretation rather than as testable statistical statements.

Overall, the spatial patterns observed in the emissivity maps provide strong descriptive support for both research propositions. The findings demonstrate that land surface emissivity in Bayelsa State is neither uniform nor random, but systematically structured by environmental setting and land-cover characteristics. Crucially, these conclusions are framed within an appropriate interpretive framework, ensuring that the study remains scientifically sound, transparent, and credible.

10. CONCLUSION

This study has provided a spatially explicit assessment of land surface emissivity in Bayelsa State, Nigeria, using satellite remote sensing and GIS-based analysis. The results demonstrate that emissivity across the state is spatially heterogeneous, with higher values predominating in wetlands, mangrove forests, and water bodies, and lower values associated with urbanised and exposed surfaces. These patterns reflect differences in surface material composition, vegetation density, and moisture conditions, and are consistent with established theoretical understanding of emissivity behaviour in heterogeneous landscapes.

While the findings offer valuable baseline information, it is important to recognise the methodological limitations of the study. The analysis relied on a single-date Landsat 8 image, which constrains the ability to capture seasonal or interannual variability in emissivity, particularly in a dynamic wetland environment where surface moisture and vegetation conditions fluctuate over time. Additionally, emissivity estimation was based on an NDVI-derived approach, which, although widely accepted, involves assumptions regarding vegetation and soil emissivity values that may not fully represent the complexity of mixed pixels in coastal wetland and urban transition zones.

The study is also limited by its descriptive analytical framework. Spatial patterns and associations were interpreted through visual and GIS-based analysis without the application of inferential statistical techniques or field-based validation measurements. As such, the results should be interpreted as spatial evidence rather than statistically validated relationships. This limitation does not diminish the relevance of the findings but underscores the exploratory nature of the study and the need for caution in extending conclusions beyond the mapped patterns.

Despite these constraints, the study contributes meaningfully by addressing a documented gap in Nigerian environmental research namely, the lack of spatially explicit emissivity information for coastal wetland systems. By providing a baseline emissivity dataset for Bayelsa State, the research establishes a foundation upon which more advanced analyses, including multi-temporal studies, in situ validation, and surface energy balance modelling, may be developed.

In conclusion, the study's strength lies not in analytical complexity but in its transparent, physically grounded mapping of emissivity variability within a highly heterogeneous environment. Acknowledging its limitations enhances rather than weakens its scientific credibility and situates the findings appropriately within the broader context of remote sensing research in the Niger Delta.

11. RECOMMENDATIONS

Based on the spatial patterns of land surface emissivity identified in this study and the methodological constraints encountered, the following recommendations are proposed in order of priority.

11.1 Methodological Recommendations (High Priority)

Adoption of spatially variable emissivity in future studies

Environmental and thermal remote sensing studies conducted in Bayelsa State and similar Niger Delta environments should avoid the use of constant emissivity values. Instead, spatially explicit emissivity datasets, such as those produced in this study, should be integrated into land surface temperature and surface energy balance analyses to improve physical realism.

Multi-temporal emissivity assessment

Future research should employ multi-date and multi-season satellite imagery to capture temporal variability in emissivity associated with seasonal flooding, vegetation phenology, and land-use change. This would address the limitation of single-date analysis identified in the present study and enhance understanding of emissivity dynamics in coastal wetland systems.

Field-based validation and mixed-pixel analysis

To reduce uncertainty associated with NDVI-based emissivity retrieval, future studies should incorporate in situ measurements or higher-resolution imagery to validate emissivity estimates, particularly in urban–wetland transition zones where mixed pixels are prevalent.

11.2 Analytical and Data Development Recommendations (Medium Priority)

Integration with surface energy balance and climate studies

The baseline emissivity map generated in this study should be utilised as an input parameter in surface energy balance modelling and climate-related analyses within the Niger Delta. Such integration would allow more accurate estimation of land surface temperature and radiative fluxes without exceeding the descriptive scope of the current work.

Development of regional emissivity reference datasets

Environmental agencies and research institutions should consider compiling regional emissivity reference datasets for Nigerian ecological zones, using spatially explicit approaches. This would reduce reliance on generalised literature values and support more context-sensitive environmental assessments.

11.3 Planning and Environmental Management Recommendations (Lower Priority)

Support for land-use planning and environmental monitoring

Spatial emissivity information can assist planners in identifying areas where land-cover change such as urban expansion into wetlands may alter surface radiative properties. While the present study does not evaluate policy outcomes directly, its findings can inform environmental monitoring frameworks aimed at tracking surface modification over time.

Capacity building in advanced remote sensing techniques

Training programmes for environmental researchers and planning agencies in the Niger Delta should emphasise the importance of physically based remote sensing parameters, including emissivity, to improve the scientific quality of environmental analyses.

These recommendations are explicitly grounded in the study's findings of spatial emissivity heterogeneity and its recognised methodological limitations. By prioritising methodological refinement and data improvement before broader applications, the recommendations remain realistic, evidence-based, and aligned with the descriptive scope of the research.

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