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INTEGRATING MULTISENSOR SATELLITE DATA TO ANALYZE URBAN HEAT ISLAND AND VEGETATION DYNAMICS IN BALI

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Introduction

Rapid urbanization in Bali alters the surface energy balance and intensifies urban heat island effects. Because the island has a monsoonal climate, daytime versus nighttime and dry versus wet season responses differ, so a multisensor approach is required. This study maps daytime and nighttime land surface temperature, quantifies seasonal SUHI across Bali, evaluates the cooling role of vegetation using NDVI, and draws practical implications for urban climate mitigation.

Literature Riview

- Physical basis of UHI framed by the surface energy balance Q* equals H plus λE plus ΔQs plus G, with urban form strongly modulating each term.
- NDVI as a proxy for canopy cover and vigor, typically showing a negative relationship with LST.
- Integration of MODIS, Landsat 8, Sentinel 2, and anthropogenic proxies such as night time lights and tropospheric NO2.
- Global findings emphasize vegetation, albedo, climate, and urban geometry, with mitigation via greening, high-albedo materials, and ventilation corridors.

Methodology

- Study area covers the whole island of Bali with focus on the southern urban belt.
- Data include MODIS LST day and night, Landsat 8 LST, Sentinel 2 NDVI, 2020 to 2025 time series, plus rainfall, NO2, and night time lights.
- Preprocessing includes reprojection, per sensor QA, grid alignment, and a shared valid pixel domain.
- Urban mask from official maps with one pixel erosion to limit mixed pixels.
- Seasonal composites for dry season May to July 2024 and wet season December 2024 to February 2025.
- SUHI defined as urban LST minus non-urban LST, with Pearson correlations and urban boundary sensitivity tests.

Result and Discussion

- Seasonal pattern: SUHI weak in dry season, strong in wet season, peak near 9 C around January 2025 in the southern core.
- Day versus night: Nighttime contrast larger than daytime.
- Drivers: Humidity and clouds slow nocturnal cooling; NDVI cools especially at night but is muted in dense urban canyons.
- Signals: LST decreases with rainfall and increases with night time lights and NO2.
- Robustness: Stable under urban boundary checks; peri urban mixing remains a caveat.

Month	Year	LST Day M	LST Night M	LST Urban M	LST Non-Urban M	SUHI	LST L	NDVI
May	2024	25.945	20.517	25.913	25.984	-0.071	20.661	0.449
June	2024	24.842	19.996	24.432	24.944	-0.512	25.655	0.438
July	2024	24.946	19.78	24.654	25.261	-0.607	26.026	0.437
December	2024	27.018	23.269	30.5	24.904	5.596	18.443	0.394
February	2025	26.293	16.865	29.635	24.616	5.019	-9,999	0.44
January	2025	26.713	20.576	32.373	23.363	9.01	29.831	0.465

Table 1: Monthly summary of daytime and nighttime LST, urban and non-urban LST, SUHI, and NDVI in Bali (May 2024 - February 2025).

Variable	Dry Season Mean	Dry Season Min	Dry Season Max	Wet Season Mean	Wet Season Min	Wet Season Max
SUHI	-0.397	-0.607	-0.071	6.542	5.019	9.010
LST Day	25.244	24.842	25.945	26.675	26.293	27.018
LST Night	20.098	19.780	20.517	20.237	16.865	23.269
NDVI	0.441	0.437	0.449	0.433	0.394	0.465

Table 2: Seasonal statistics of SUHI daytime LST nighttime LST and NDVI in Bali (Dry 2024 and Wet 2024 - 2025).

Period	Mean LST (°C)	Mean NDVI	Mean Rainfall (mm)
May - July 2024	32.825	0.153	54.562
December 2024 - February 2025	19.947	0.080	711.449

Table 3: Two seasonal window summaries from the 2020 - 2025 series in Bali (May - July 2024 and December 2024 - February 2025).

Variable Pair	r (Pearson)	N (Months)
LST vs Rainfall	-0.564	62
LST vs NO_2	0.388	62
LST vs NTL	0.551	62
NDVI vs Rainfall	-0.572	62

Table 4: Pearson correlations among key variables from monthly data 2020 - 2025 in Bali.

Conclusion

- Fusing MODIS, Landsat 8, and Sentinel 2 effectively captures seasonal UHI and vegetation dynamics in Bali.
- SUHI is weak in the dry season and intensifies in the wet season, peaking in the southern urban core.
- NDVI shows a more consistent cooling effect at night, while the direct NDVI to SUHI relation is not strong in the limited sample.
- Practice priorities include peri-urban greening, higher albedo and lower heat capacity surfaces, and wind corridors, monitored within a consistent multisensor framework.
- Future work should extend the time window, keep a common valid domain, and add vegetation metrics and urban morphology classes for stronger attribution.

Acknowledgments

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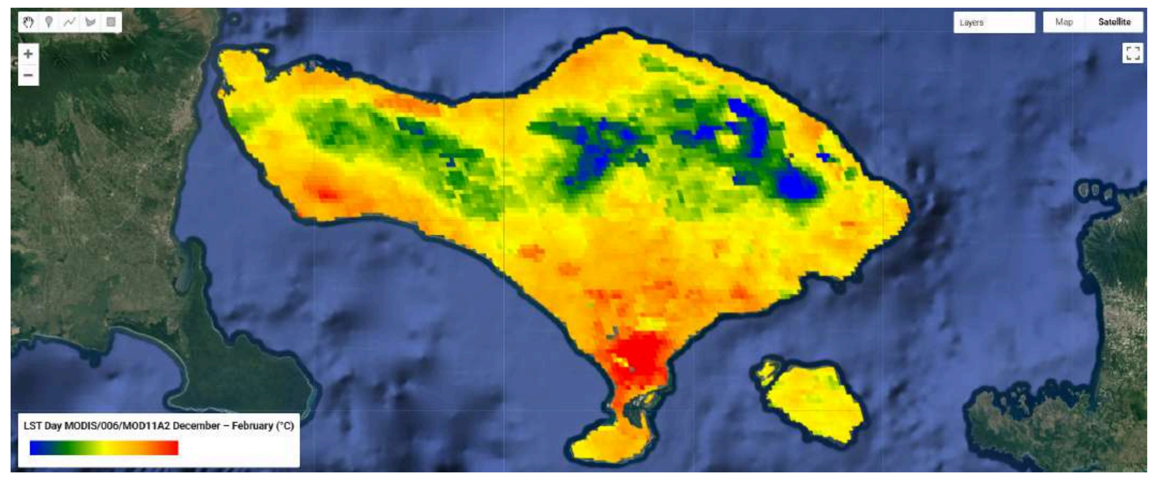

Figure 1: Daytime land surface temperature (LST) during the wet season (degrees Celsius). Warmer values are concentrated in southern Bali.

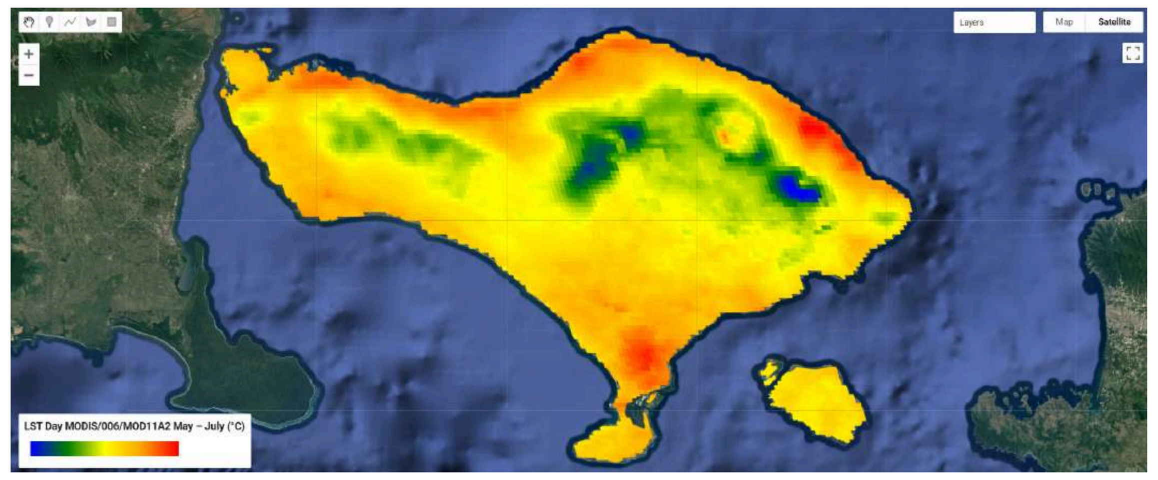

Figure 2: Daytime LST during the dry season (degrees Celsius), showing cooler pockets that follow the central mountain range.

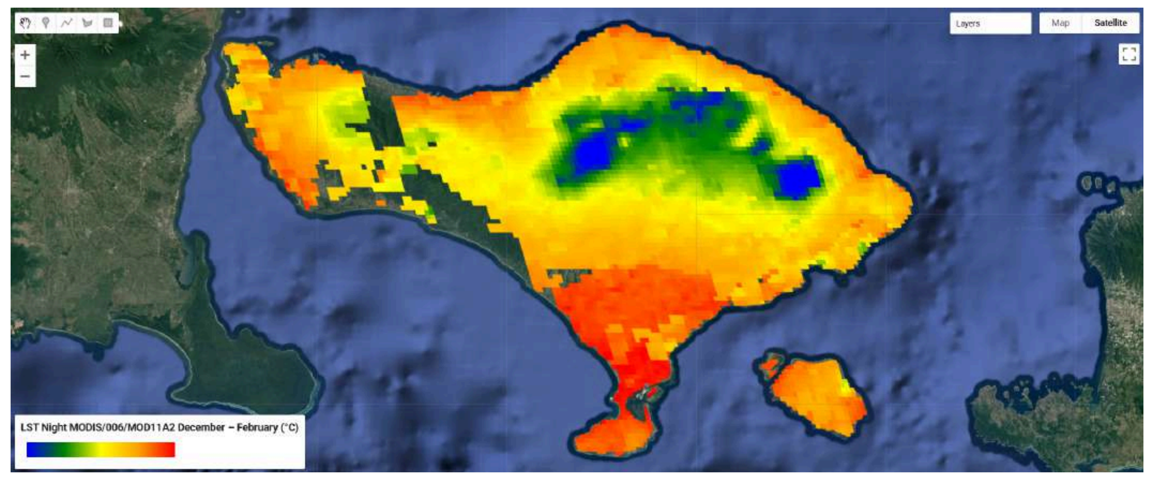

Figure 3: Nighttime LST during the wet season, with southern Bali remaining warmer than the central highlands.

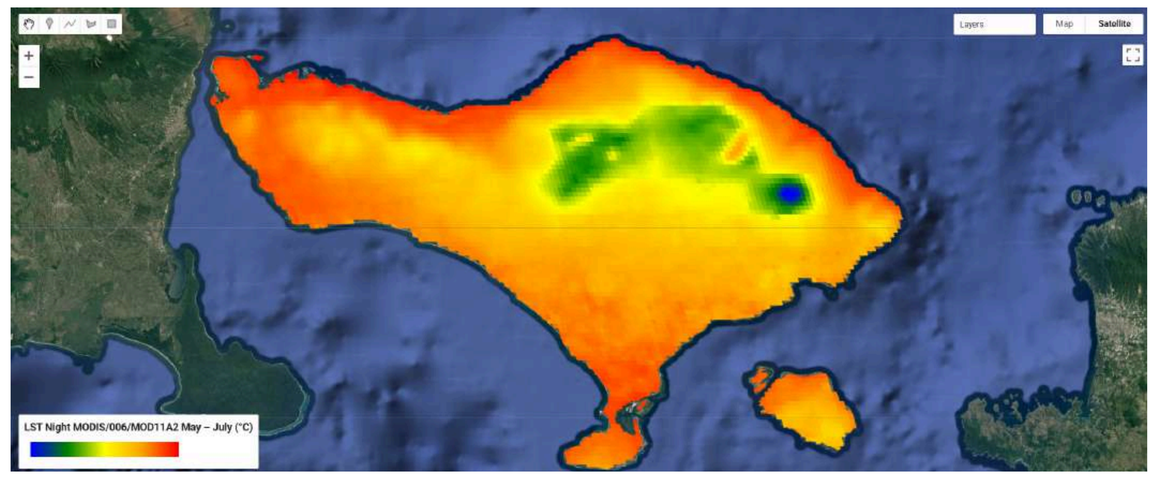

Figure 4: Nighttime LST during the dry season; the south to north contrast is still visible but weaker.

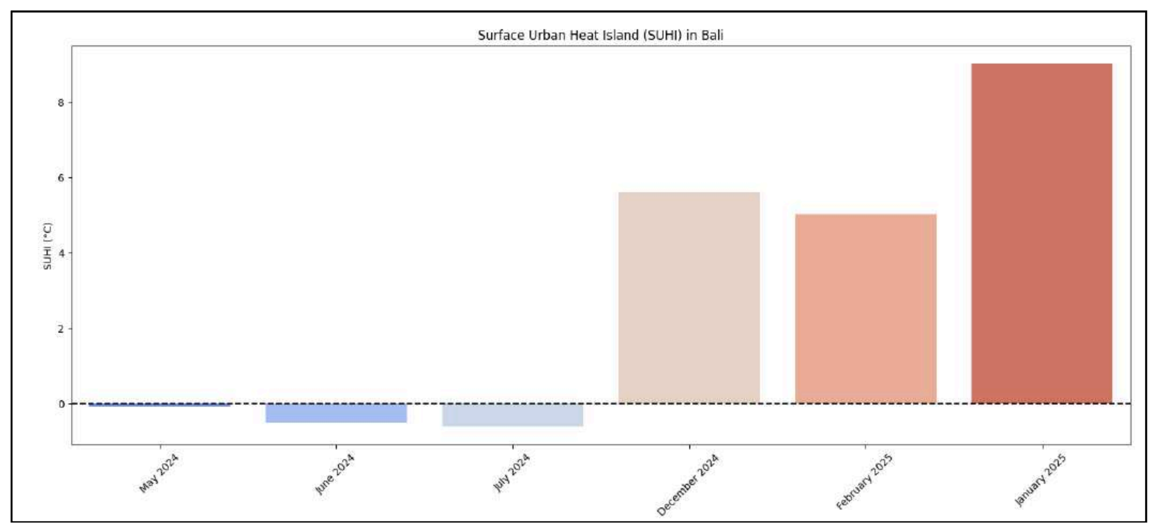

Figure 5: Monthly SUHI with a zero reference line to highlight sign changes.

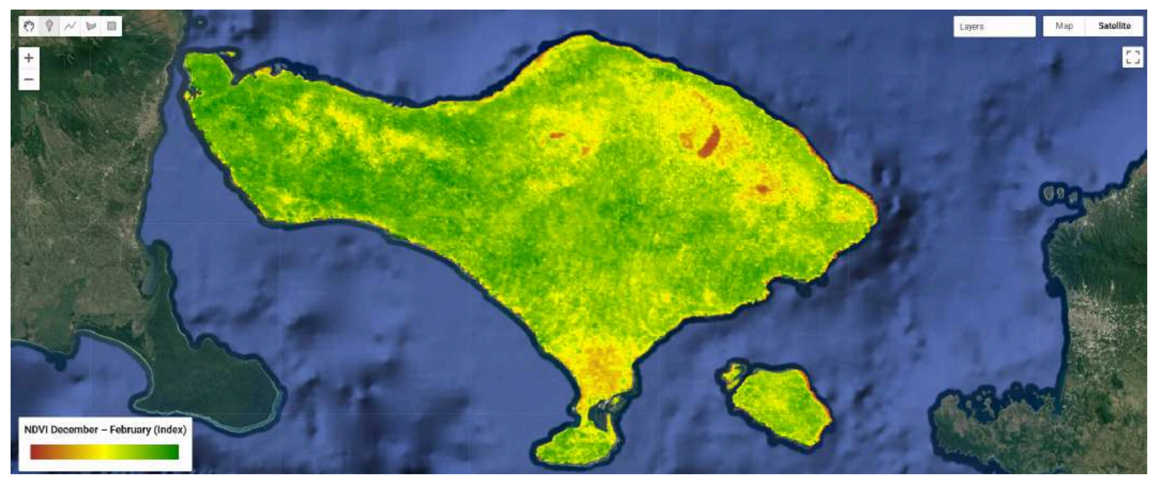

Figure 6: NDVI during the wet season (unitless index), indicating relatively sparser vegetation in parts of the south.

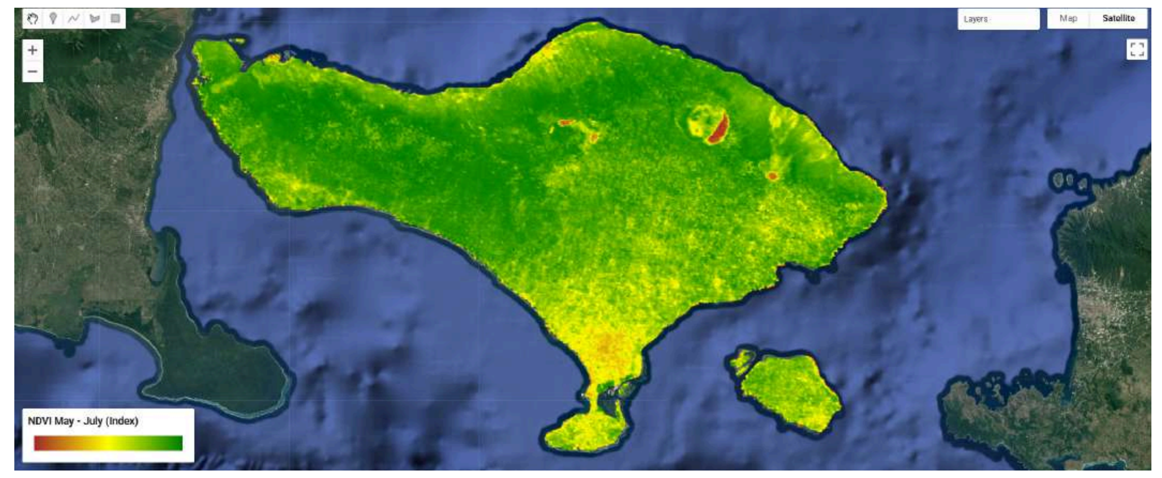

Figure 7: NDVI during the dry season, with higher values across many land areas, especially in the central to eastern zones.

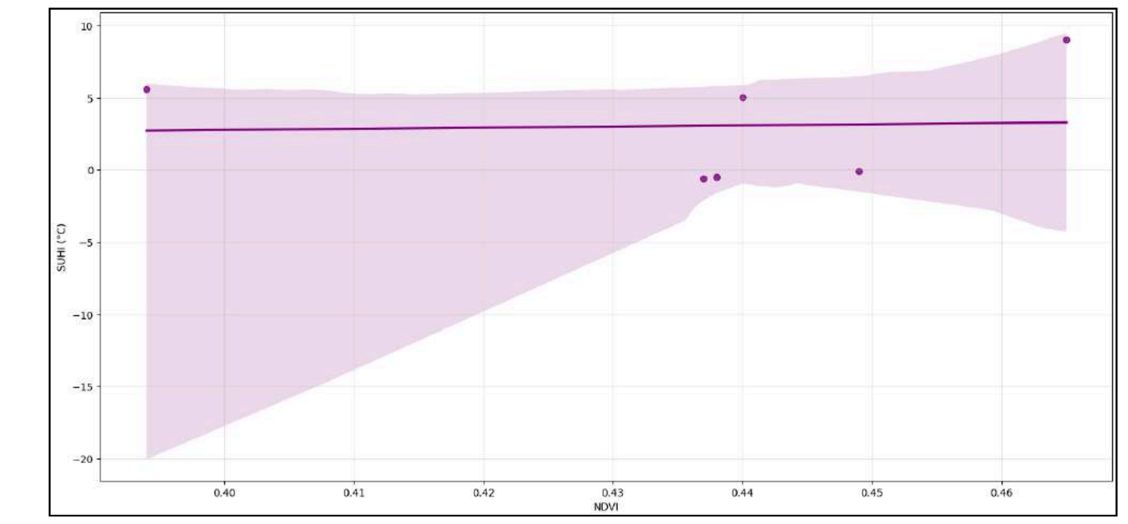

Figure 8: Relationship between NDVI and SUHI; the shallow slope indicates a weak direct association for the six month sample.

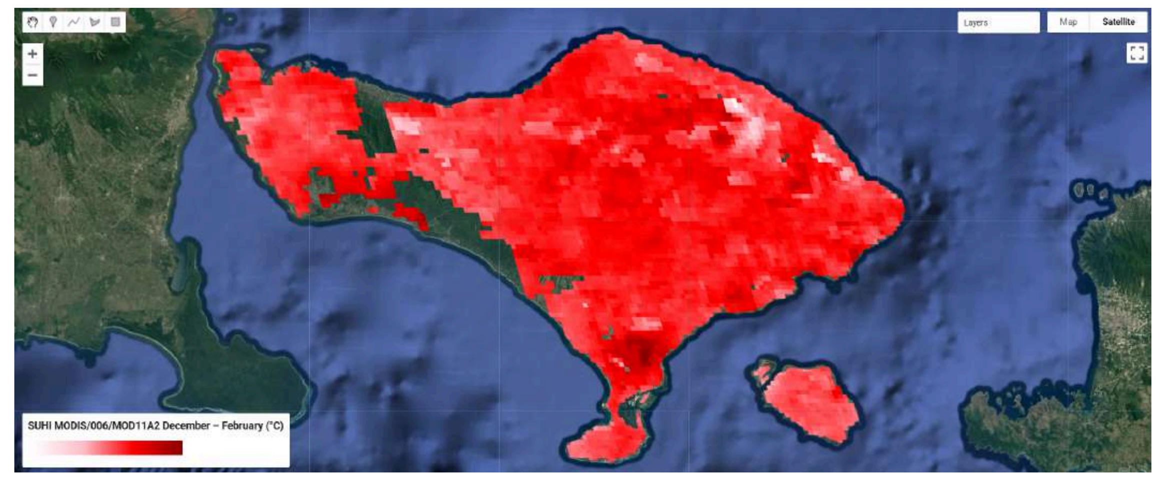

Figure 9: Surface urban heat island (SUHI) during the wet season, expressed in degrees Celsius and defined as urban LST minus non urban LST.

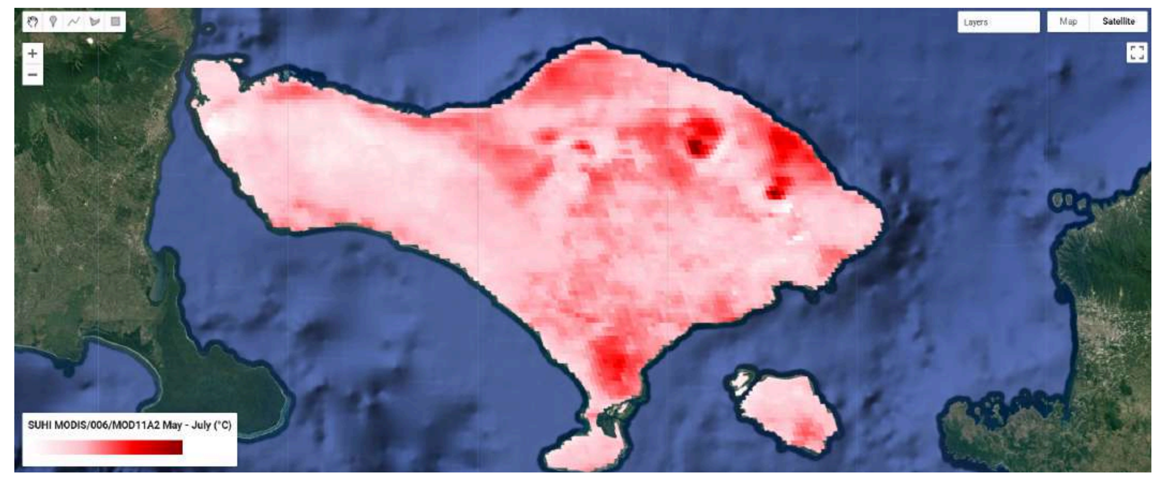

Figure 10: SUHI during the dry season, showing a weaker urban to non-urban contrast.

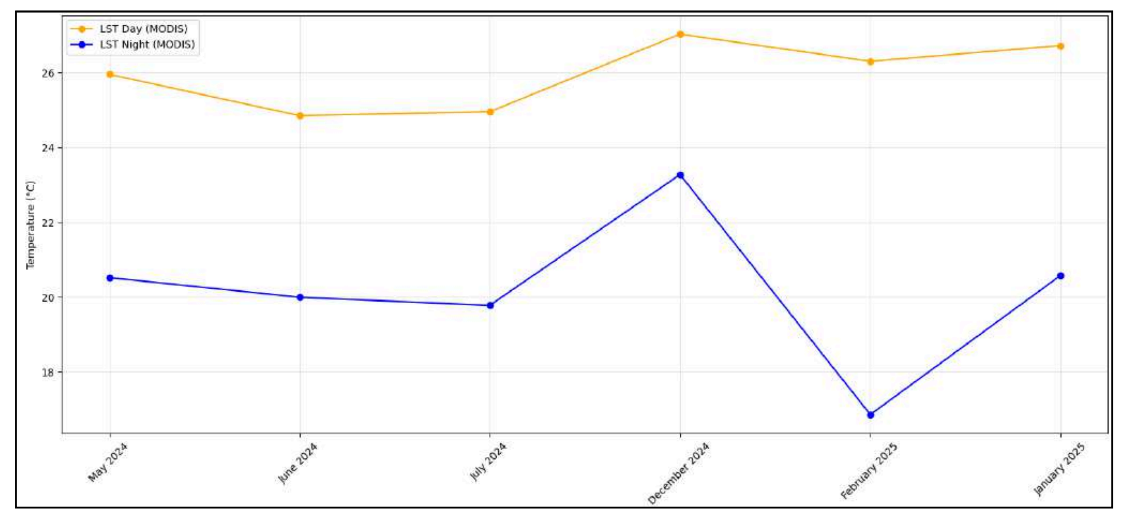

Figure 11: Contrast between daytime and nighttime LST across the six months.

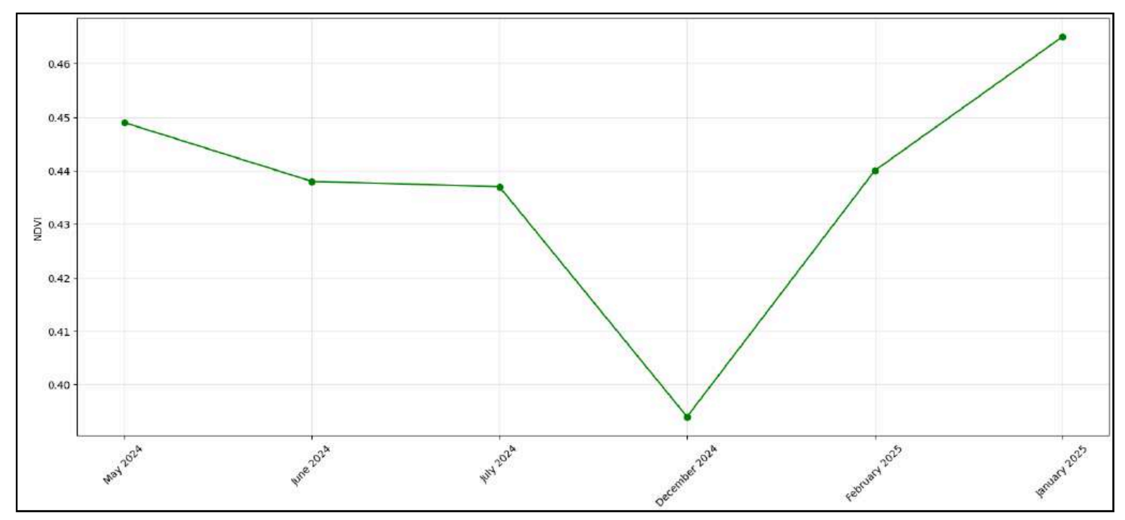

Figure 12: Monthly NDVI across the two seasonal windows.