INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ORIGINAL ARTICLE

Check for updates

OPEN ACCESS

Received: 09/10/2025

Accepted: 09/11/2025

Published: 02/12/2025

Citation: Lalruatkimi C, Devi KB, Khanna N, Tripathi OP (2025) Influence of Land Use Patterns on Microclimatic Variables in Dampa Tiger Reserve, Mizoram. Indian Journal of Science and Technology 18(44): 3515-3523. https://doi.org/10.17485/IJST/v18i44.1675

* **Corresponding author**.

cruatkimi24@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Influence of Land Use Patterns on Microclimatic Variables in Dampa Tiger Reserve, Mizoram

C Lalruatkimi[1]*, Khumanthem Babina Devi[1], Nistha Khanna[1], Om Prakash Tripathi[1]

1 Department of Environmental Science, School of Earth Sciences and Natural Resources Management, Mizoram University, Aizawl- 796004, Mizoram, India

Abstract

Objectives: Local climatic conditions directly influence organismal performance and ecosystem functioning. Understanding spatial and temporal variations in microclimatic variables is crucial in the current rapidly changing landscapes. Thus, the present study investigates how microclimatic variables such as air temperature, relative humidity, and soil temperature vary across diverse land use systems in Dampa Tiger Reserve, Mizoram. **Methods:** Six land use types were selected, namely primary forest, secondary forest, shifting cultivation, and monoculture plantations of oil palm, teak, and areca nut. Mid-day air temperature, relative humidity, and soil temperature measurements were recorded under each land use system on a seasonal basis− pre-monsoon, monsoon, and post-monsoon seasons. An ART analysis of variance (ANOVA) was conducted to examine the impact of land use on the microclimatic variables. **Findings:** Primary forest exhibited lower temperature and higher relative humidity compared to the modified land use systems across all seasons. Air and soil temperature peaked during the pre-monsoon season, while relative humidity was at its lowest across all land use types. Primary forest showed the greatest thermal buffering during the pre-monsoon period, with temperatures 4.46°C below the seasonal mean, while the current jhum was 3°C higher than the average. Air temperature and soil temperature were strongly positively correlated (ρ = 0.82, P < 0.01), whereas relative humidity was negatively correlated with air (ρ = -0.45, P < 0.01) and soil temperature (ρ = -0.62, P < 0.01). **Novelty:** Unlike previous studies in the tropics focusing on single season or single variable, the present study examines how shifts in land use systems and seasons together influence the key microclimatic variables. The findings of the present study strengthen our understanding of land use change impacts on seasonal microclimatic variables and will assist decision makers and local stakeholders in making informed decisions regarding sustainable land use practices.

Keywords: Land use; Microclimate; Soil temperature; Seasonal variation; Forest

1 Introduction

Forests are among the most productive ecosystems on earth and play a significant role in the Earth's biogeochemical cycles and also regulate climate at the regional and global scale[(1)]. Conversion of forest to non-forested land use systems such as agriculture land, plantation, urban land, etc. have been identified as one of the greatest threats to forest and the global climate stability. This in turn, adversely affects the composition, diversity, structure, and the ecosystem services they provide[(2)], [(3)]. In this context, changes in ecosystems exert significant influence on the regulation of climate patterns at the macro, meso, and micro spatial scale[(4)] Microclimates can be defined as the local climate conditions that organisms or ecosystems are exposed to[(5)]. They can be characterized by a wide range of variables, or combinations of variables such as air temperature, rainfall, solar radiation, humidity, evaporation, direction and speed of wind, water availability, and soil temperature and moisture. Variability in microclimates is strongly governed by topography and vegetation[(6)]. Vegetation influences microclimate by regulating air temperature, moderating wind speed, controlling the amount of solar radiation and partly modifying the spectral composition[(7)]. This in turn is determined by the species composition, structure, and level of disturbances (natural or anthropogenic). Therefore, changes in vegetation have significant impacts on the local climatic conditions; for instance, in Malaysia, a 1.5 to 2.3 °C rise in temperature and a significant reduction in humidity were observed when peat swamp forests were converted to oil palm plantations[(8)].

Dampa tiger reserve (DTR), situated within the Indo-Burma biodiversity hotspot, represents one of the biologically rich and ecologically important landscapes in Northeast India. Like many other protected areas in India, the areas surrounding the core zone of the reserve have undergone significant changes in land use pattern. These include shifting cultivation (jhum), human settlements, monoculture plantations of cash crops such as oil palm, areca nut, teak, and rubber[(9)]. Such transformations lead to changes in forest species composition and structure, habitat fragmentations, and changes in ecological process. Land use change effects on wildlife habitat and soil physiochemical properties have been addressed by previous studies[(9)], [(10)], [(11)]. However, little is known about their influence on the local climatic conditions. Understanding how micro-climatic parameters vary across diverse land use systems is essential for assessing their ecological impacts and for framing management and conservation strategies. Thus, our study aimed to assess the broad seasonal patterns of key microclimatic variables such as air temperature, relative humidity, and soil temperature across selected land use systems in Dampa tiger reserve, Mizoram. We hypothesized that forest stands have a more stable micro climatic conditions with lower soil and air temperature and higher humidity than other land use systems. We also hypothesized that seasonal effect on the microclimatic variables is significant across the land use systems.

2 Methodology

2.1 Study site

Dampa Tiger Reserve is located in the western part of Mizoram, India at 23°32'42" – 23°41'36" N latitude and 92°13'12" – 92°27'27" E longitude (Figure 1) The elevation ranges from 200 to 1100 m above mean sea level, and the mean annual rainfall is 2,150 mm which falls mainly during May to October. Dominant forest types include tropical evergreen, semi-evergreen, and moist deciduous forest. The reserve is divided into two management zones namely the core zone, covering an area of 545km^2 and the buffer zone, with an area of 488 km^2. The core zone is under rigid protection with minimal human disturbance while the multi-use buffer zone is a mosaic of shifting cultivation also known as jhum, fallow jhum land, traditional agroforestry, plantations, settlements and home gardens[(12)]. For the present study, six land use systems in the core and buffer zones of DTR were selected, namely primary forest (located inside the core zone of DTR with minimal human disturbance –PF), secondary forest (regenerating forest after shifting cultivation – SF), current jhumland (active shifting cultivation where the major crop is rice – CJ), and monoculture plantation of oil palm plantation (OP), teak (T), areca nut (AN).

2.2 Method

Temperature and relative humidity under each land use types were measured using a hygrothermometer positioned 1m above the ground. Soil temperature reading was determined by inserting soil thermometer at a depth of 0–5cm from the surface. Measurements were conducted from 2022 to 2023 across three distinct seasons– pre-monsoon (January – April), monsoon (May – August), post-monsoon (September – December) to capture seasonal variations. Readings were taken during the day at standardized time (midday hours) across each land use systems and measurements were avoided during extreme weather condition to minimize potential bias. Hourly air temperature and relative humidity data were retrieved for from the NASA POWER database (https://power.larc.nasa.gov/), to illustrate the diurnal variation in air temperature and relative humidity.

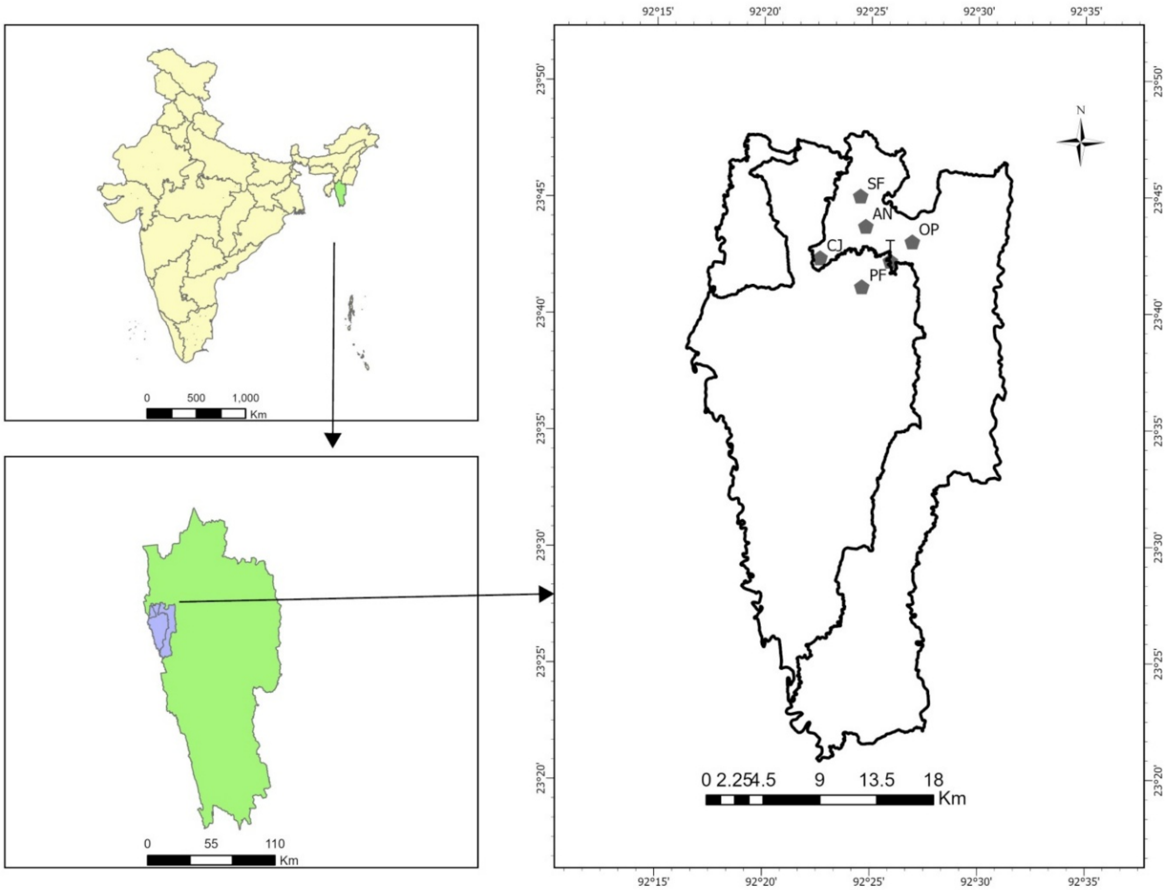

Fig 1. Map showing locations of sampling points in the study site

These values were compared with field-measured values to contextualize the midday microclimatic conditions across land use types.

2.3 Data Analysis

The collected data were tested for normality and homogeneity of variance using Shapiro–Wilk and Levene's test. Since the assumptions of normality were not satisfied, a non-parametric ART (Aligned Rank Transform) ANOVA was performed to examine the effects of land use and seasons on each microclimatic variable followed by pairwise comparison using ART-C post hoc test for multiple comparisons [13].

Correlation analysis was performed to examine the relationships among the measured variables using the Spearman's rank correlation coefficient. To quantify deviations in microclimatic parameters across land use types and seasons, a seasonal anomaly analysis was conducted. Principal Component Analysis was performed to summarize the variability in microclimatic variations and identify which variables best discriminate among land use systems. All Statistical analyses and visualization were performed using R software (version 4.3.0).

3 Results and Discussion

3.1 Effects of land use and seasons on air temperature, relative humidity, and soil temperature

Mean values of microclimatic variables are presented in Table 1 to aid descriptive interpretation, however statistical inferences are based on the ART-ANOVA result. The air temperature was recorded to be highest during the pre-monsoon season across all land use systems with significant reduction during the monsoon and post-monsoon seasons. According to the ART-ANOVA, the main effects of land use (F=12.55, P <0.001) and season (F=138.99, P<0.001) on air temperature were significant, whereas their interaction effect was not significant across the different land use types (F=1.09, P>0.05). The findings indicated that seasons exhibited a strong influence on air temperature and that seasonal pattern of air temperature was consistent across land use. The primary forest exhibited the lowest air temperatures across all seasons, whereas the current jhum recorded the highest temperatures throughout. Among the monoculture plantations, oil palm exhibited the lowest seasonal air temperatures compared to areca nut and teak plantations. The main effects of land use (F=31.17, P < 0.001) and seasons (F= 235.71, P< 0.001) as well as their interaction effects (F=5.97, P<0.001) were found to be significant on the measured relative humidity. The relative humidity across each land use types displayed the following increasing seasonal pattern: pre-monsoon < post-monsoon < monsoon. The pronounced increase in relative humidity during the monsoon season reflects the period when wind carry moisture laden air from the ocean to the land areas [14]. The results also indicated that the primary and secondary forests, and oil palm plantations retained higher relative humidity even during the dry (pre-monsoon) season. In addition, the soil temperature was significantly affected by land use (F=11.04, P<0.001) and season (F = 66.70, P<0.001) as well as their interaction (F=3.122, P<0.001). Seasonal soil temperature pattern revealed that it was the highest during the pre-monsoon, followed by monsoon and post-monsoon season across all land use systems (Figure 2). The observed midday values of air temperature and relative humidity during post- monsoon season and diurnal variation of one example day (5th December 2022) are illustrated in Figure 3 to contextualize the field daytime result.

Table 1. Seasonal mean value (±SD) of microclimatic variables across land use systems

Seasons	Land Use	Air Temperature (°C)	Relative Humidity (%)	Soil Temperature (°C)
Pre-Monsoon	PF	28.9±3.06	62.2±4.07^{c}	24.3±1.21^{a}
	SF	31.2±3.04	51.3±9.35^{b}	29.8±3.31^{b}
	CJ	34.4±2.94	47.5±5.86^{c}	35.5±6.83^{b}
	OP	30.7±4.43	56.7±9.75^{b}	28.3±2.25a^{b}
	T	32.9±4.98	47.7±5.05^{c}	29.2±2.14^{b}
	AN	32.2±3.27	48±2.61^{b}	29.8±2.79^{b}
Monsoon	PF	24.5±0.45	93.7±0.52^{a}	23±0.63^{a}
	SF	25±0	68.7±0.52^{a}	25±0^{b}
	CJ	28.5±0.39	64.5±3.83^{a}	26.7±0.52^{c}
	OP	28.5±0.45	71±2^{a}	25±0^{a}
	T	28±0.05	69.2±1.6^{a}	25±0^{b}
	AN	28.8±0.31	66.7±0.52^{a}	25±0^{c}
Post-Monsoon	PF	20.8±1.07	69.8±1.47^{b}	19.5±2.26^{a}
	SF	22.2±0.28	59.5±4.14^{b}	21.8±2.79^{b}
	CJ	24.8±1.32	54.3±0.52^{b}	22.7±3.33^{c}
	OP	23.4±3.27	68.7±0.52^{a}	22.3±4.84^{a}
	T	23.6±1.76	62.7±3.01^{b}	25.2±0.40^{b}
	AN	25.2±2.7	62.2±4.13^{a}	25.5±0.83^{d}

PF: Primary forest, SF: Secondary forest, CJ: Current jhum, OP: Oil palm, T: Teak, AN: Areca Nut. Different uppercase letters are significantly different (p < 0.05) between land use within each season.

The marked increase in air and soil temperature and decline in relative humidity with the land use shift from forest to oil palm, teak and areca nut plantations, and jhum cultivation could be attributed to increase in canopy gaps and reduction in canopy diversity in these modified land use systems. The dense vegetation in the primary forest reduced the amount of solar radiation reaching the understory, thereby keeping the ambient temperature cooler than the adjacent land use types [15]. Similar finding is reported from northern Ecuador, where air temperature was found to increase significantly when forest is converted

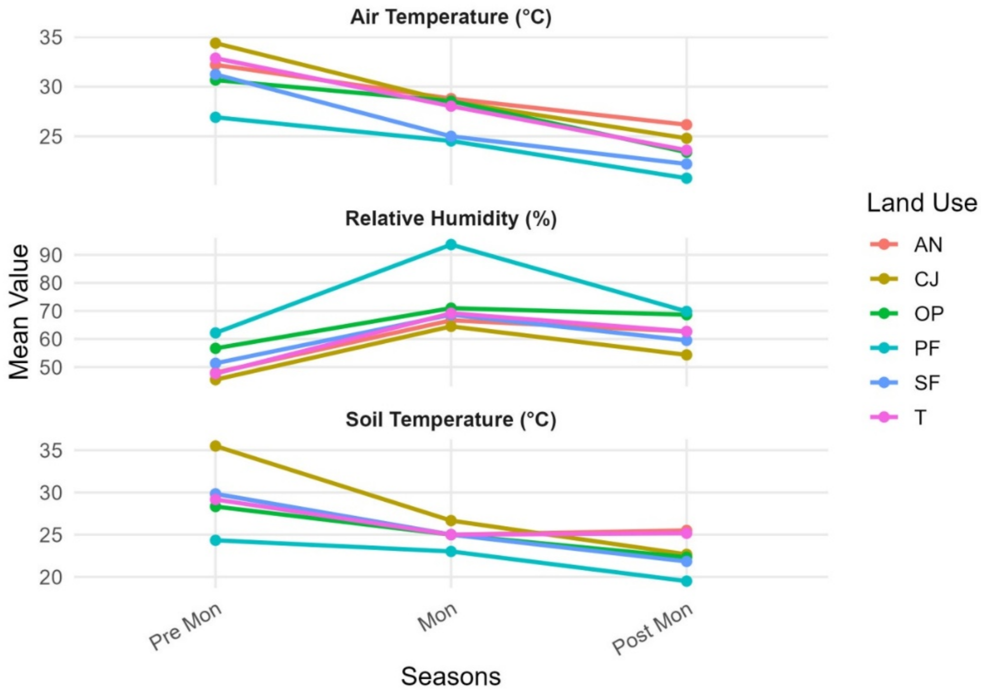

Fig 2. Seasonal variations in microclimatic variables across different land use systems

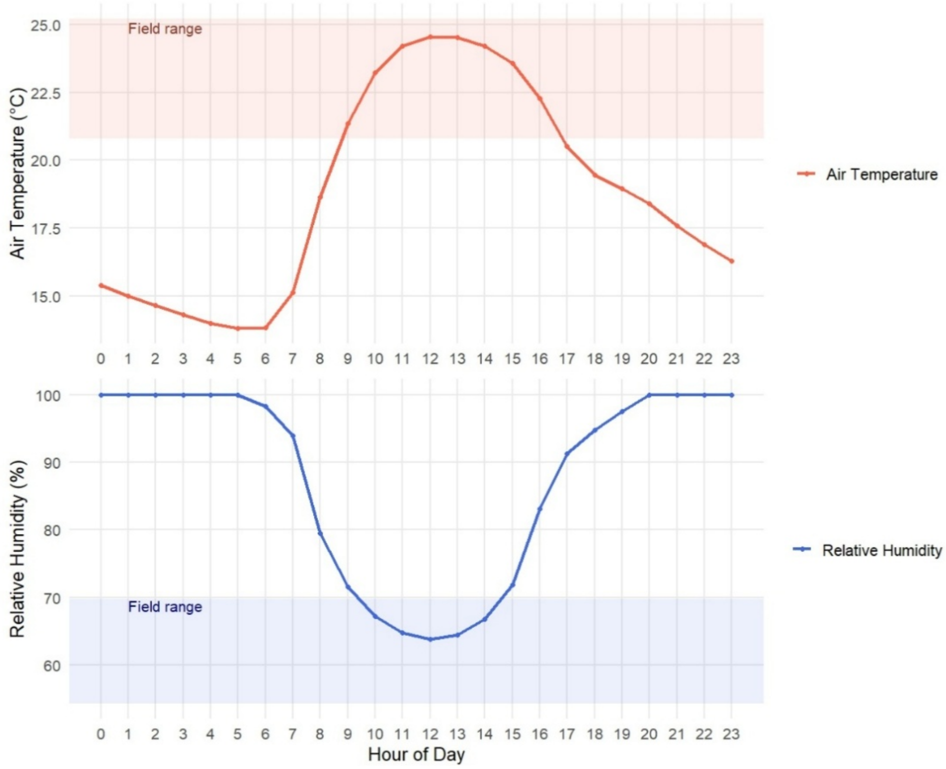

Fig 3. Diurnal variation of air temperature (°C, red line) and relative humidity (% RH, blue line) on 5 December 2022. Shaded areas represent the observed field ranges for air temperature (pink) and relative humidity (blue)

to monoculture plantation, pastures, and planted forest[4]. Though soil has higher inertia than air, the land use transformation effect on soil remains notably significant, as is evidenced by the current examination. This observation is consistent with the findings of similar study in southern Ethiopia, where soil temperature under open land area was reported to be significantly higher than two plantation forests[16]. In addition, the complex vertical structure of the primary forest plays a significant role in regulating the relative humidity. Vegetation influences humidity by absorbing water from a ground source and releasing it into the atmosphere through a process known as transpiration. The regulation of humidity under the forest is further complemented by photosynthesis, shading, and wild shielding effect of the vegetation. A notable increase in air and soil temperature at the CJ site during the pre-monsoon coincides with the clearing and burning phase of the jhum cycle, during which the soil is exposed with minimal vegetation cover. The bare soil is exposed to direct sunlight, and the lack of vegetation minimizes shading and evapotranspiration effects, thereby raising the temperature in the current jhum site[17].

In contrast to open areas, closed canopy cover as observed in the primary forest site of the present study, exhibited moderate temperature due to controlled sunlight penetration and wind. Similarly, in tropical regions like Delhi and New Mexico, a relatively stable daytime microclimatic conditions were recorded which could be attributed to the large and continuous vegetation cover and the related evapotranspiration process[18] Lenk et al. stated that forest canopy provides buffering effect resulting in reduction of extreme climatic conditions[19]. The regulating effect of canopy is not just limited to its structure, but also to its composition. In the present study, primary forest and secondary forest with more diverse crown structure and composition exhibited reduced temperature and retained moisture under their cover[20]. This reflects the greater regulating effect of diverse canopy cover compared to monoculture plantation and tree-less jhum cultivation sites.

3.2 Relationship among the microclimatic variables

The Spearman correlation analysis revealed a significant positive relationship between air temperature and soil temperature (ρ = 0.82, P < 0.01), indicating that shifts in the ambient temperature are closely mirrored by the corresponding soil temperature. In contrast, the relative humidity showed a significant negative relationship with both air (ρ = -0.45, P < 0.01) and soil temperature (ρ = -0.62, P < 0.01). This suggests that an increase in air temperature, the capacity of air to hold moisture decreases, resulting in reduced relative humidity[21].

3.3 Seasonal Anomaly Analysis

The deviations in the microclimatic variables from the seasonal means across the land use types are illustrated in Figure 4. During the pre-monsoon season, the current jhum exhibited the highest positive anomalies in both air (3°C) and soil temperatures (6°C), while the primary forest displayed the lowest anomalies, with 4.46°C and 5.17 °C lower air and soil temperature than the regional mean, suggesting that these land use systems deviate strongly from the seasonal mean. In contrast, the relative humidity exhibited an opposite pattern, with primary forest experiencing the highest positive anomaly (10%) and the current jhum the most negative anomaly, with 6.39% lower than regional mean, further highlighting the contrasting microclimatic conditions. The secondary forest showed the least deviation from the seasonal norm with just 0.14°C lower than the regional mean, while the oil palm, teak, and areca nut plantations exhibited moderate microclimatic deviations from the seasonal mean. During the monsoon season, the areca nut plantation was observed to be 1.57°C warmer than the regional mean, while the primary forest was 2.7°C cooler than the regional mean. A pronounced increase in relative humidity was observed in the primary forest relative to the regional norm, as indicated by the large positive anomaly (20%). In addition, the current jhum also experienced a significant reduction in relative humidity compared to the seasonal norm (-7.78%). The strongest positive deviation in soil temperature (1.72 °C) was observed in the current jhum, whereas primary forest displayed the lowest negative anomaly at -1.93°C. During the post-monsoon season, the warmest air and soil temperatures were exhibited by the areca nut plantation, both with a degree of 2.67 warmer than the seasonal mean. Meanwhile, the air and soil temperatures in the primary forest were 2.71°C and 3.33°C cooler than the regional mean respectively. The high positive humidity anomalies and negative temperature anomalies by the primary forest across all the seasons further suggest its greater thermal buffering and moisture retention capacity than the regional average[15].

3.4 Principal Component Analysis (PCA) of microclimatic variables across land use types

The PCA biplot showed that 77.1% and 16.7% of the total variance was explained by the first two principal components (PC1 and PC2), which accounts for 94.4% of the cumulative variance in the data **(Fig.5)**. PC1 exhibited a strong positive association with air and soil temperature, and negative correlation with relative humidity. A distinct grouping pattern was observed among land use, the current jhum and areca nut plantation clustered toward the positive side of PC1, reflecting higher air and soil temperatures and lower humidity, In contrast, the primary forest and oil palm plantation and secondary forests exhibited

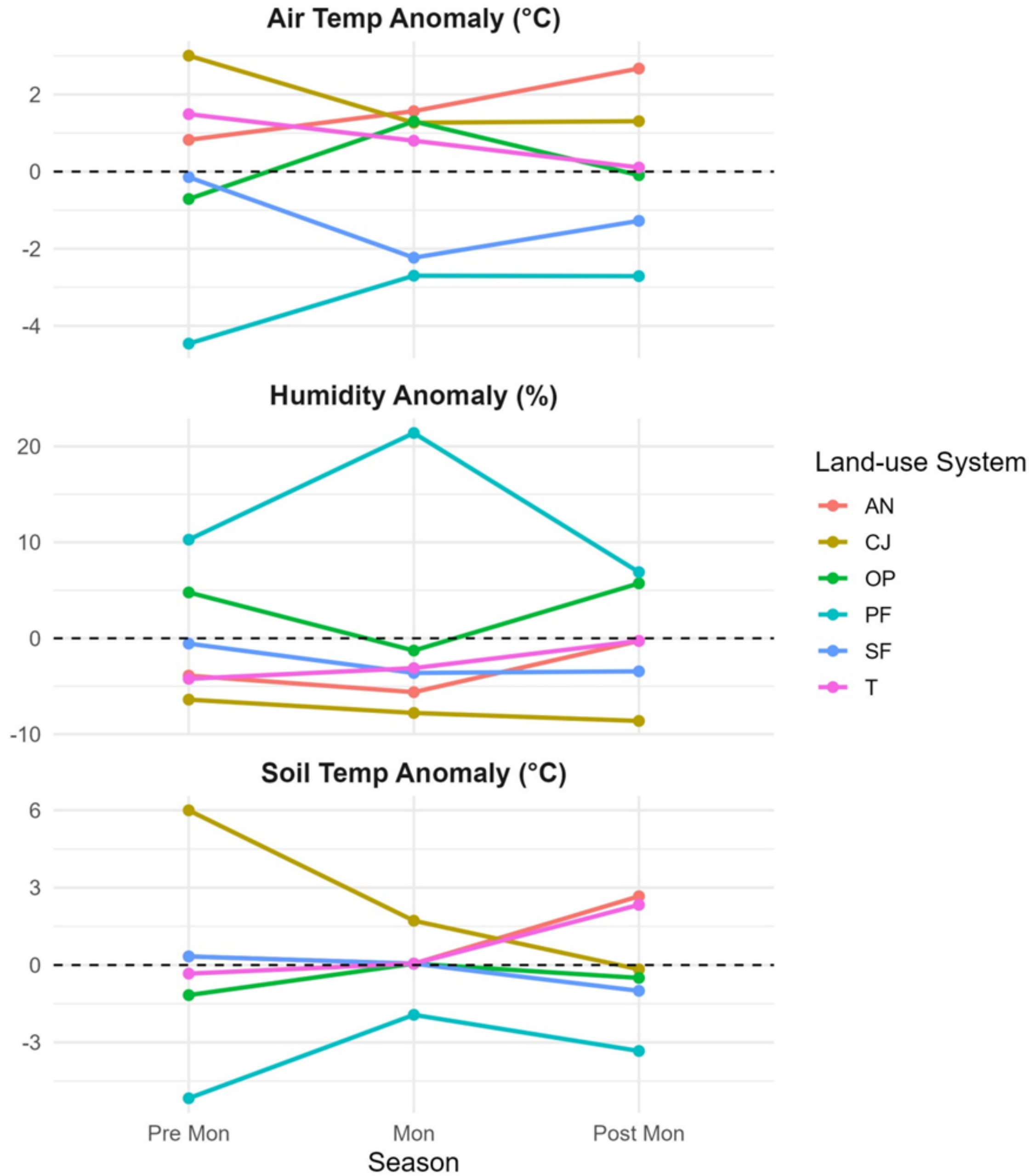

Fig 4. Seasonal anomalies of air temperature, relative humidity, and soil temperature across land use types

an opposite clustering pattern, corresponding to higher humidity and lower air and soil temperatures. Overall, PCA biplot indicated that among the measured variables, air temperature and soil temperature are the key variables discriminating among the land use. The strong loading of both air and soil temperature along the principal component axes further suggests that land-use changes can significantly alter energy balance and heat flux near the ground surface[7]. Therefore, microclimatic regulation through vegetation management plays a crucial role in maintaining ecosystem stability and resilience in different land-use systems.

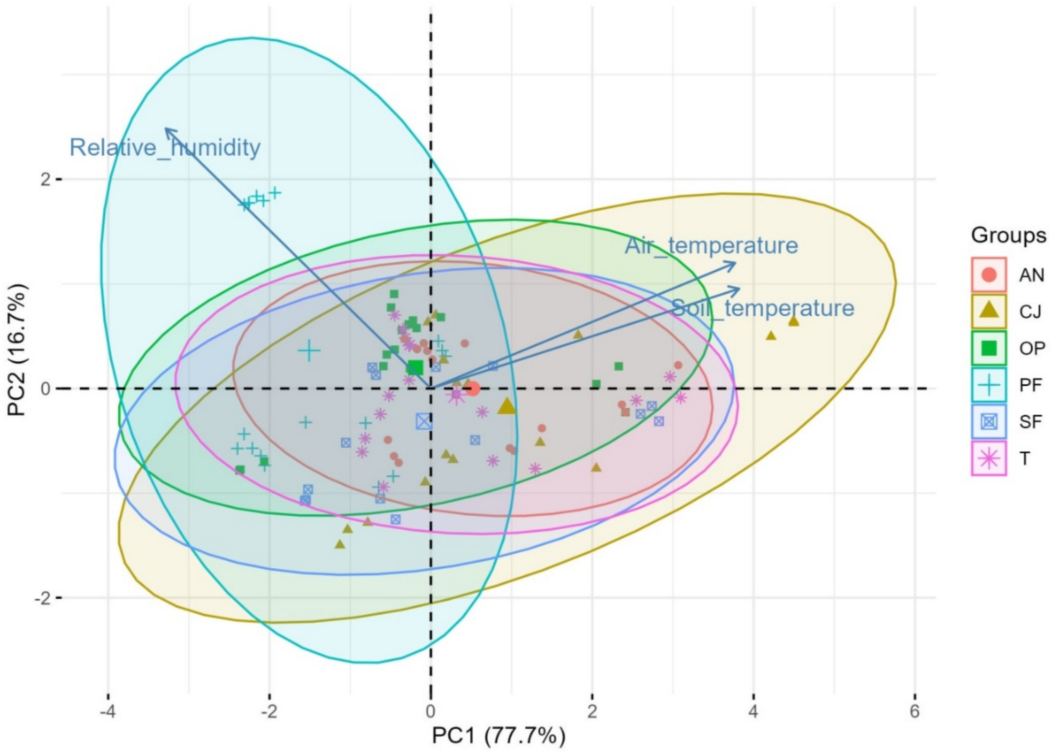

Fig 5. Principal Component (PCA) biplot showing separation of land use based on microclimatic variables

4 Conclusions

The study observed that the conversion of forests to monoculture plantations of oil palm, teak and areca nut, and jhum cultivation have significant impact on the microclimate variables such as air temperature, relative humidity, and soil temperature. The modified land use systems recorded hotter and drier air condition, as well as higher soil temperature. The buffering effect of undisturbed primary forest was stronger during the pre-monsoon season. Considering the direct influence of microclimates on the growth and survival of species, and the functioning of an ecosystem, the study presents some preliminary findings that enhance our understanding of how certain microclimatic variables respond to land conversion. Since the present study focused exclusively on peak daytime data, therefore, further research incorporating nighttime measurements to capture the full diurnal variation is recommended.

5 Acknowledgements

The first author gratefully acknowledges the University Grants Commission for providing the financial assistance through JRF fellowship to conduct this research. The authors are thankful to the Department of Environment, Forests and Climate Change, Government of Mizoram for granting permission to undertake this research within the DTR, and to the forest officials and local field guides for their valuable assistance and support during the fieldwork.

References

1) Jaiswal N, Jayakumar S. Biomass patterns in Srivilliputhur Wildlife Sanctuary: exploring factors and gradients with machine learning approach. *Environ Monit Assess*. 2024;196:434. 10.1007/s10661-024-12591-5.
2) Khadanga SS, Dar AA, Jaiswal N, Dash PK, Jayakumar S. Elevation patterns of tree diversity, composition and stand structure in Mahendragiri Hill Forest, Eastern Ghats of Odisha, India. *J Asia-Pac Biodivers*. 2023;16(3):391–405. 10.1016/j.japb.2023.04.004.
3) Mengist W, Soromessa T. Assessment of forest ecosystem service research trends and methodological approaches at global level: a meta-analysis. *Environ Syst Res*. 2019;8:22. 10.1186/s40068-019-0150-4.
4) Trávez W, Guarderas P. Land use affects the local climate of a tropical mountain landscape in Northern Ecuador. *Mt Res Dev*. 2023;43. 10.1659/MRD-JOURNAL-D-21-00016.
5) Frenne PD, Beugnon R, Klinges D, Lenoir J, Niittynen P, Pincebourde S, et al. Ten practical guidelines for microclimate research in terrestrial ecosystems. *Methods Ecol Evol*. 2025;16:269–294. 10.1111/2041-210X.14476.
6) Kemppinen J, Lembrechts JJ, Meerbeek KV, Carnicer J, Chardon NI, Kardol P, et al. Microclimate, an important part of ecology and biogeography. *Glob Ecol Biogeogr*. 2024;33(6):e13834. 10.1111/geb.13834.
7) Mughal OM, Kubilay A, Fatichi S, Meili N, Carmeliet J, Edwards P, et al. Detailed investigation of vegetation effects on microclimate by means of computational fluid dynamics (CFD) in a tropical urban environment. *Urban Clim*. 2021;39:100939. 10.1016/j.uclim.2021.100939.
8) Anamulai S, Sanusi R, Zubaid A, Lechner A, Ashton-Butt A, Azhar B. Land use conversion from peat swamp forest to oil palm agriculture greatly modifies microclimate and soil conditions. *PeerJ*. 2019;7:e7656. 10.7717/peerj.7656.
9) Gouda S, Sethy J, Chauhan N, Bargali H. Study on the impacts of LULC change on the wildlife habitat and the livelihood of people in and around Dampa Tiger Reserve, Mizoram, India. *J Threat Taxa*. 2021;13:18986–18992.
10) Mandal J, Raman TRS. Shifting agriculture supports more tropical forest birds than oil palm or teak plantations in Mizoram, northeast India. *Condor Ornithol Appl*. 2016;118(2):345–359. 10.1650/CONDOR-15-163.1.
11) Gouda S, Decemson H, Zoramkhuma, Malsawmdawngliana F, Biakzuala L, Lalremsanga HT. Threat assessment and conservation challenges for the herpetofaunal diversity of Dampa Tiger Reserve, Mizoram, India. *J Threat Taxa*. 2023;15:24016–24031. 10.11609/jott.8590.15.10.24016-24031.
12) Lalruatkimi C, Devi KB, Mohamed AA, et al. Seasonal Variation in Soil Quality across Different Land Use Systems in Dampa Tiger Reserve, Mizoram, India. *Eurasian Soil Sci*. 2025;58:102. 10.1134/S1064229324604633.
13) Elkin LA, Kay M, Higgins JJ, Wobbrock JO. An aligned rank transform procedure for multifactor contrast tests. *Proc 34th Annu ACM Symp User Interface Softw Technol*. 2021;p. 754–768. 10.48550/arXiv.2102.11824.
14) Khan PI, Ratnam DV, Prasad P, Basha G, Jiang JH, Shaik R, et al. Observed climatology and trend in relative humidity, CAPE, and CIN over India. *Atmosphere*. 2022;13(2):361. 10.3390/atmos13020361.
15) Zellweger F, Coomes D, Lenoir J, Depauw L, Maes SL, Wulf M, et al. Seasonal drivers of understorey temperature buffering in temperate deciduous forests across Europe. *Glob Ecol Biogeogr*. 2019;28(12):1774–1786. 10.1111/geb.12991.
16) Alem S, Madera P, Pavlis J. Soil temperature in an open site and below two plantation forest canopies in a tropical highland area, southern Ethiopia. *Theor Appl Climatol*. 2020;139(3):907–914. 10.1007/s00704-019-03031-3.
17) Feng X, Wen H, He M, Xiao Y. Microclimate effects and influential mechanisms of four urban tree species underneath the canopy in hot and humid areas. *Front Environ Sci*. 2023;11:1108002. 10.3389/fenvs.2023.1108002.
18) Kara Y, Yavuz V. Urban microclimates in a warming world: land surface temperature (LST) trends across ten major cities on seven continents. *Urban Sci*. 2025;9(4):115. 10.3390/urbansci9040115.
19) Lenk A, Richter R, Kretz L, Wirth C. Effects of canopy gaps on microclimate, soil biological activity and their relationship in a European mixed floodplain forest. *Sci Total Environ*. 2024;941:173572. 10.1016/j.scitotenv.2024.173572.
20) Stickley S, Fraterrigo J. Understory vegetation contributes to microclimatic buffering of near-surface temperatures in temperate deciduous forests. *Landsc Ecol*. 2021;36:1–17. 10.1007/s10980-021-01195-w.
21) Tang M, Li W, Gao X, Wu P, Li H, Qiang L, et al. Land use affects the response of soil moisture and soil temperature to environmental factors in the loess hilly region of China. *PeerJ*. 2022;10. 10.7717/peerj.13736.