

**ASSESSMENT OF TREE DIVERSITY, HABITAT
CHARACTERISTICS AND HUMAN-WILDLIFE CONFLICT IN
DAMPA TIGER RESERVE, MIZORAM**

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
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AND HUMAN-WILDLIFE CONFLICT IN DAMPA TIGER RESERVE,
MIZORAM**

**BY
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**Submitted
In partial fulfillment of the requirement of the Degree of Doctor of Philosophy
in Environmental Science of Mizoram University, Aizawl.**



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SUPERVISOR'S CERTIFICATE

This is to certify that the Thesis entitled **“Assessment of tree diversity, habitat characteristics and human-wildlife conflict in Dampa tiger reserve, Mizoram”** submitted by **C Lalruatkimi** for the degree of Doctor of Philosophy (Ph.D.) in **Environmental Science**, embodies the record of original investigation carried out by her under my guidance and supervision. This Thesis or any part thereof has not been submitted for any degree of any other University.

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**DECLARATION
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DECEMBER, 2025**

I **C LALRUATKIMI**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to do the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

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ABBREVIATIONS

<u>Short form</u>	<u>Expanded form</u>
AIC	Akaike Information Criterion
AK	Available Potassium
AN	Available Nitrogen
ANOVA	Analysis of Variance
AP	Available Phosphorus
CI	Confidence Interval
DBH	Diameter at Breast Height
DTR	Dampa Tiger Reserve
FIVI	Family Importance Value Index
GBH	Girth at Breast Height
GEE	Google Earth Engine
GIS	Geographic Information System
GPS	Global Positioning System
HSD	Honestly Significant Difference
HWC	Human-wildlife Conflict
IBA	Important Bird Area
IUCN	International Union for Conservation of Nature
IVI	Important Value Index
LULC	Land Use Land Cover
MDS	Minimum Data Set
NLUP	New Land Use Policy
NTFPs	Non-timber Forest Products
OR	Odd Ratio

PC	Principal Component
PCA	Principal Component Analysis
pH	potential of Hydrogen
RS	Remote Sensing
SD	Standard Deviation
SE	Standard Error
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SPSS	Statistical Package for the Social Sciences
SQI	Soil Quality Index
USGS	United States Geological Survey
UV	Ultraviolet
WHC	Water Holding Capacity

1.1. Overview of forest ecosystems, biodiversity, functions, and services

Forests harbor a vast majority of the earth's terrestrial biodiversity and are one of the most ecologically significant ecosystems on the planet (Tinya et al., 2021). It is reported that 31% of the total land area is under forest cover, spanning over 4.06 billion hectares. However, these forests exhibit an uneven distribution across the globe with more than half (54 %) of the world's total forests present in only five countries namely, the Russian Federation, the United States of America, Brazil, Canada, and China. The largest percentage (45%) of the global forests is in the tropical regions, followed by the boreal (27%), temperate (16%), and sub-tropical (11%) (FAO, 2020). Forest biodiversity encompasses all the life forms present in forested areas and the ecological roles that they play. Thus, trees and the myriad of animals, plants, fungi, micro-organisms, and their associated genetic diversity constitute forest biological diversity (Jenkins & Schaap, 2018). Several studies have confirmed that forest biodiversity has significant contribution towards the forest ecosystem functions and services (Brockerhoff et al., 2017). These include provision of habitat, clean air and water, food, fiber, medicine, alongside regulation of climate, water, air, erosion, and landslides. Furthermore, forests play a vital role in nutrient cycling, pollination, and biological pest control while also providing aesthetic, cultural, and spiritual benefits (Brockerhoff et al., 2017; Mengist & Soromessa, 2019). They are also one of the most productive ecosystems on earth, and play a significant role in the earth's biogeochemical cycles while also regulating climate at the local, regional and global scale (Barrufol et al., 2013).

Studies have extensively explored the relationship between diversity and productivity, and many of these studies have established that diversity is positively correlated with forest productivity; consequently, the loss of forest biodiversity would result in significant decline in productivity (Liang et al., 2016). Forests serve as major terrestrial carbon sinks by converting atmospheric carbon into biomass through the process of photosynthesis (Kafy et al., 2023). According to the IUCN (2021), forests sequestered nearly one third of the carbon dioxide emissions

generated by the global fossil fuel combustion. The capacity of forestlands to capture and store carbon is greatly reduced when they are converted to other land use systems (Haseeb et al., 2024; Legesse et al., 2024; MacLean et al., 2021; Nath et al., 2021; Toru & Kibret, 2019; Wang et al., 2023). This highlights the substantial influence that forests have on climate and their critical role in mitigating impacts of climate change. The different ecosystem functions and services, including the capacity to sequester and store carbon, and forest productivity are influenced not only by the species diversity, but also by stand structure and functional diversity (Aerts & Honnay, 2011).

1.2. Threats and challenges facing forest ecosystems

The ever increasing anthropogenic demands exert an overwhelming pressure on forest resources, leading to accelerated degradation and deforestation. Deforestation involves complete removal of forest cover and replacing it with other land use types. Whereas, forest degradation refers to a permanent or temporary disturbance on forest, typically due to selective logging, fires, fragmentation, mining, and extraction of forest resources. Generally speaking, deforestation results in complete loss of forest, while degradation reduces the quality or health (Souza et al., 2024). Nevertheless, they both exert adverse impacts on the composition, diversity, structure of forests, and the ecosystem services they provide (Khadanga et al., 2023; Mengist & Soromessa, 2019). An estimated amount of 10 million hectares of forest are cut down each year and almost all (95%) of forest loss occurred in the tropics, which is the richest region in terms of biodiversity. Two main factors have been identified for forest loss worldwide- extraction of forest resources and conversion of forest to alternate land use systems (FAO, 2020). At the global level, studies from 1190 to 2023 revealed that agriculture expansion remained the principal driver of deforestation. Commercial farming of cash crops such as oil palm, rubber, tobacco, and others was identified as the major driver of deforestation. In the meantime, the contributions of small scale subsistence as well as semi-subsistence farming towards deforestation still remained highly relevant (Feurer et al., 2025). Extraction of woods, either in the form of large-scale commercial logging or small-scale logging is another key driver of deforestation (Adetoye, 2019; Devi & Shimrah, 2022;

Feurer et al., 2025). There are regional variations in the drivers of forest loss. For instance, the predominant driver of forest loss in Russia and North America is wildfire, while expansion of agriculture, particularly through oil palm cultivation remained the major reason for forest loss in Indonesia and Malaysia. Meanwhile, urbanization is responsible for a small fraction of total forest loss worldwide (Curtis et al., 2018). Expansion of pasture land for cattle rearing, oilseeds plantations and commercial tree plantations for paper and wood emerged as prominent drivers for forest loss in Brazil (FAO, 2020). Wood extraction was identified as the dominant factor driving forest degradation in some parts of the world, while shifting agriculture emerged as the major driver, particularly in tropical countries (Aditya & Ganesh, 2019; Uvsh et al., 2020). In India, increasing land use for permanent agriculture was identified as the key driver for forest loss, followed by settlements and infrastructure development, and mining (World Resources Institute, 2025). The problems associated with these key drivers are exacerbated by an increase in population growth and population density (Feurer et al., 2025).

1.3. Land use land cover change and ecosystem degradation and conservation

Land use land cover change (LULC) is perhaps the most common form of global environmental change (Roy & Roy, 2010). Land use change and intensification of anthropogenic land use remains the greatest threat to forest landscape (Lindenmayer et al., 2023). Around 75 % of the global and surface has been altered by anthropogenic activities, which is strongly correlated with biodiversity loss and disruption of ecosystem functions and services (Pulido-Chadid et al., 2023). Previous studies have established that land use effects on biodiversity vary significantly across different biomes and ecosystem types. For instance, conversion of land to agricultural fields may reduce species diversity and number of individuals in the tropical forest ecosystems, whereas the same kind of conversion may increase biodiversity in the deserts (García-Vega & Newbold, 2020). An analysis of local terrestrial biodiversity in the context of land use change estimated a global reduction in average within sample richness by 13.6%, rarefaction-based richness by 8.1%, and total abundance by 10.7%. In the worst affected habitats, the effect is more pronounced with a reduction in within-species richness by an average

of 76.6%, rarefaction-based richness by 39.5%, and total abundance by 39.5%. A local species richness loss exceeding 20% exhibited a substantial likelihood of impairing the biodiversity's contribution to ecosystem function and services (Newbold et al., 2015). Assessing species diversity and community attributes in human-modified land use systems and non-degraded forest is vital for understanding the response of forest communities to land use change.

The effects of land use and land cover changes extend beyond biodiversity; as such changes exert significant impacts on the climate at the micro, meso and macro scales. They are known to impact the climate through two distinct pathways. One is the biogeophysical pathway involving alterations in surface albedo, sensible and latent heat fluxes, soil temperature and moisture. The other is the biogeochemical pathway involving changes in the concentration of greenhouse gases in the atmosphere (Brovkin et al., 2013). Climatic regulation at the micro scale is typically achieved through the biophysical pathway rather than the biogeochemical pathway (Trávez & Guarderas, 2023). Forests function as biophysical thermo-regulators of the microclimate by affecting evapotranspiration and albedo. Conversion of forests to other land use systems will result in higher albedo, absorbing lesser radiation but, drier condition due to the release of net radiation in large amounts as sensible heat (Faye et al., 2014). Vegetation cover regulates microclimatic conditions as a function of their nature, composition, structural attributes, and ecophysiological behavior. Thus, modifications in vegetation and soil coverage exert pronounced influence on the air temperature, relative humidity, soil temperature and moisture content, and wind speed at the local level (Aussenac, 2000). Studying the response of the general microclimatic variables will provide valuable insights on the effects on land use patterns on local climate conditions.

The quality of soil and its productivity and sustainability relies on the dynamic balance among the biological, chemical, and physical properties which are significantly influenced by land use systems (Nanganoa et al., 2019; Tellen & Yerima, 2018). Characterizing soil quality variations across multiple spatial scales offers valuable insights into the impacts of land management practices on soil health. According to Larson & Pierce (2015), the soil may be judged based on five functions of soil, they are- the capacity to retain and release moisture to vegetation,

water cycle, and subsoil; to store and release vital nutrients and other important chemicals; to promote root development; to respond to quality enhancement and withstand degradation; and to support important soil biota. Although it is not feasible to quantify soil quality directly, it can be achieved through the assessment of its physicochemical and biological properties (Deepana et al., 2025). The responses of different soil quality parameters varied significantly across land use types in their magnitude and direction. In Rib watershed, Ethiopia, the natural forest soil exhibited higher pH, organic carbon, organic carbon stock, and total nitrogen compared to soils of cultivated lands (Buruso et al., 2023). Similarly, Ewunetu et al. (2025) found that land use significantly altered soil properties with intense degradation of soil observed in the modified land use systems. Bulk density was found to increase with land-use intensity, whereas soil organic carbon, total nitrogen, and exchangeable bases decreased with use intensity. Across the soil profile, the impact of soil properties is most pronounced in the top soil as it is directly exposed to land management systems (Li et al., 2025). Land use change and its associated alterations in soil properties remain a challenge in the world's most ecologically significant tropical region. It is therefore essential to quantify land use change impacts on soil quality in this region.

Beyond its impacts on ecosystem processes, land use change also alters the spatial distribution and behavior of wildlife. As natural habitats are degraded or converted for agriculture, settlement, and infrastructure, wildlife is increasingly displaced from its native ranges. This often leads to greater overlap between human activities and wildlife habitats, resulting in escalating human–wildlife conflicts (HWC) in many parts of the world. Human-wildlife conflicts can be defined as interactions that generate negative outcomes for one or both parties. HWC tends to intensify when there is an increase in competition for the same resources like food, water, or space (König et al., 2021). For example, in Nepal's Trans-Himalayan region, land use changes have altered the foraging patterns of blue sheep by pushing them to lower altitudes. This shift, in turn has drawn the snow leopards from their higher-altitude habitats to lower-elevation sites, which are closer to human settlements, resulting in increased human-wildlife conflicts in the region (König et al., 2021). The intensity of HWC can range from minor to severe, and its frequency

may vary from rare to common. The abundance and distribution of conflict has been hypothesized to be a factor of the distribution of food and water (Nyhus, 2016). Animals engaged in HWCs may range from grain-eating small rodents to large mammals such as elephants and lions. The nature, extent, frequency, and species involved in conflicts differ across regions. For instance, in India, elephants, wild pigs, rodents, primates, and birds are widely recognized as major crop raiders. Meanwhile, leopards, wild dogs, and jackals are among the top ranked animals responsible for livestock depredations. Human injuries and deaths resulting from wild animal attacks are more common in areas where people share the same space with bears, leopards, elephants, and sloth bears (Karanth et al., 2012; Manral et al., 2016). Research indicates that certain crops and livestock are more prone to destruction than others. Food crops like rice, maize, wheat, sugarcane, and lentils are more susceptible to raiding than cash crops (Gross et al., 2018). HWCs typically consist of four main types- crop raiding, livestock depredation, human attack, and property damage. These negative interactions often lead to huge economic loss, threaten livelihood, and food security, and negatively impact mental health and overall well-being. Over time, they can also lower public tolerance toward wildlife and reduce support for conservation initiatives (Barua et al., 2013). Previous studies have shown that declining wildlife population and in some cases, localized species extinction are often the result of hostile responses and retaliatory killings following HWCs (Long et al., 2020). Therefore, unresolved HWCs pose serious challenges to conservation efforts, human well-being, and sustainable livelihoods. Hence, a comprehensive understanding of HWCs and their driving factors is essential to implement effective conservation strategies.

1.4. Role of protected areas in biodiversity conservation, ecosystems functioning and challenges

In an effort to counter the declining rate of biodiversity and protect ecosystem structure, functions and services, several protected areas are established across the globe (Geldmann et al., 2019). They are one of the key tools for safeguarding ecosystem integrity and conserving biological diversity. These protected areas encompassed 16.6% and 7.7% of terrestrial and marine ecosystems respectively

(Pulido-Chadid et al., 2023). The Kunming-Montreal Global Biodiversity Framework further calls for the expansion of protected areas to 30% of the global land and water. Across 31 studies on the influence of protected areas on species population, it was reported that populations performed better within the protected areas compared to the control sites (non-protected areas). In addition, several studies reported the effectiveness of protected areas in maintaining habitats and curbing habitat loss, especially those that have been established for longer periods (Geldmann et al., 2013). Li et al. (2024) stated that protected areas were 33% more effective in preventing habitat loss compared to unprotected areas. A detailed worldwide analyses of site-level data on a large, taxonomically broad set of species showed that the inside of protected areas supported more individuals and species than outside, which is mainly attributed to differed land use between protected and unprotected areas (Gray et al., 2016). For instance, primary forest within the Lore Lindu National Park, Indonesia supported higher tree species richness than adjoining forest gardens, secondary forests, and cacao plantations (Kessler et al., 2005). Land degradation and alteration do not merely reduce biodiversity and habitat integrity, but also affect the global climate. Protected areas play a significant role in sequestering and storing atmospheric carbon and minimize the impact of climate change. In addition, they are also effective at regulating the regional microclimate. Natural or semi-natural vegetation within protected areas are effective in cooling the land surface temperature compared to the non-protected area consisting mostly of human-modified land use. This cooling effect is more pronounced during the day. Furthermore, protected forests exhibit thermal buffering effects especially in the tropical and temperate regions, hence offering refuge for important species (Xu et al., 2022).

The effectiveness and potential of a protected area to an extent is a function of the surrounding landscape (Hansen & De Fries, 2007). Recent studies have highlighted the growing significance of conserving biodiversity beyond protected areas to meet conservation objectives and enhance livelihood security (Aye & Shibata, 2023). The different land use type and intensity surrounding protected areas exert varied effects on protected areas and should be considered in isolation. Many protected areas are likely to face increasing pressure from land use change and

socioeconomic dynamics in the coming decades (De fries et al., 2007). Studies suggest that protected areas are threatened by increased human pressure in various forms such as land use change, pollution, invasive species, hunting, and other threats (Ghosh-Harihar et al., 2019). Specifically, increased anthropogenic activities around protected areas have been linked to higher rates of species extinction and illegal resource extraction within them.

The loss of protected area functionality and integrity due to changes in the surrounding landscapes not only weakens biodiversity conservation and ecosystem services but also alters the movement pattern of wildlife. These issues pose significant challenges especially in developing nations (Bailey et al., 2016). Land use practices within and surrounding protected areas often result in alterations in landscape structure by reducing vegetation cover and habitat connectivity, leading to increasingly irregular or fragmented habitat patches. As natural habitats become increasingly fragmented or degraded, interactions between humans and wildlife increase, often resulting in heightened human–wildlife conflict (Distefano, 2003).

1.5. Mizoram

Mizoram, located in the Northeastern part of India falling within the Indo-Burma biodiversity hotspot supports immense diversity of plants and animals. According to the India State of Forest Report (2023), 85.34% of land in Mizoram is under forest cover, making it the state with the highest percentage in the country. Out of this, only 1.24% is under very dense forest, 40.96 under moderately dense, 43.14 under open forest (Forest Survey of India, 2023). Agriculture is the primary source of livelihood for the people in Mizoram, with shifting cultivation (Jhum) has traditionally been the dominant agricultural practice. However, recent years, shifting cultivation has been increasingly replaced by plantations of oil palm, areca nut, rubber, and teak in different parts of the state (Lungmuana et al., 2019). The expansion of agriculture, uncontrolled wildfire, indiscriminate felling of trees, over exploitation of forest resources, and land use land cover alterations collectively exert immense pressure on Mizoram's forests, leading to a significant reduction in the quality and quantity of forest in the state (Sati, 2022). Furthermore, land use

changes driven by anthropogenic activities have resulted in decline in soil quality, particularly in hilly areas like Mizoram, characterized by fragile ecosystem and soils that are highly vulnerable to degradation. To conserve Mizoram's rich biodiversity, maintain ecological balance, and enhance ecosystem functions and services, several protected areas have been established in the state. These include two national parks, seven wildlife sanctuaries, and one tiger reserve and over 25 reserved forests. These protected areas are surrounded by human habitations, majority of which belong to tribal populations. Continuous population expansion in the state leads to increased biotic pressure on protected areas and reserve forests (Sethy & Chauhan, 2013). Dampa Tiger Reserve (DTR) constitutes the largest protected area in Mizoram, and is home to a rich diversity of flora and fauna. The reserve supports one of the highest population densities of clouded leopard within their range in continental Southeast Asia (Singh & Macdonald, 2017). In addition, a new *Begonia* species, *Begonia dampae* was also discovered from the reserve (Odyuo et al., 2018). It further represents one of the last remaining habitats for Malayan sun bear in Mizoram as well as the northeastern region (Sethy & Chauhan, 2013). However, like many protected areas in India, the surrounding landscapes of DTR are experiencing extreme anthropogenic pressures from land use change, expansion of human settlements, and habitat fragmentation (Gouda et al., 2021). Such disturbances not only threaten ecosystem sustainability and habitat suitability, but also modify vegetation composition and structure, thereby influencing tree diversity, habitat characteristics, and escalating human-wildlife conflict in and around the reserve.

1.6. Study objectives:

Given the growing human pressures around the reserve and their ecological consequences, this study seeks to understand how land use changes affect tree diversity, habitat characteristics, and the pattern and occurrence of human-wildlife conflict. In line with this aim, the study was designed with the following specific objectives-

1. To assess the spatio-temporal extent of land use/land cover changes in Dampa Tiger Reserve.
2. To study the microclimate, soil characteristics, tree diversity and community characteristics in the different land use types of Dampa Tiger Reserve.
3. To evaluate perceptions and attitudes of people regarding human-wildlife conflict, and identify the drivers for mitigation measures.

Considering these objectives, the following hypothesis were formulated:

H₁: Tree species diversity and community attributes differ significantly across the different land use types

H₂: Site characteristics and soil properties vary significantly across the across the different land use types

H₃: The pattern and distribution of human-wildlife conflict vary across crop type and proximity to DTR core

H₄: The perceptions and attitudes towards wildlife conservation DTR is influenced by people's socio-economic background

CHAPTER 2

REVIEW OF LITERATURE

2.1. Land use land cover change (LULC)

The face of the earth has seen many changes over the past few centuries, and the role of human beings in altering the land cover has drastically increased (Roy & Roy, 2010). This could be attributed to rapid growth in population, leading to an increase in demand for land resources (Yadav et al., 2012). Land resource is used mainly for food production, grazing of livestock, settlement, infrastructure extension, and others (Arowolo & Deng, 2018). There are a variety of driving forces that alter land use and land cover, and these factors bring about diverse changes in land cover, depending upon the specific environmental, social, political, and historical context in which they arise. In addition, the nature and magnitude of land cover change induced by these factors vary considerably across space and time (Nagendra et al., 2004). Land use/land cover, being dynamic in nature, offers a comprehensive understanding of the relationship and impact of our activities on the environment (Prakasam, 2010; Yadav et al., 2012). Changes in land use and land cover have their effects on biodiversity, water, climate, soil, and the overall functioning of an ecosystem, either positively or negatively (Lambin et al., 2001). Investigating and monitoring land use/land cover change that has either undesired or beneficial effects on the environment call for special attention. The advancement in remote sensing and Geographical Information Systems (GIS) have enabled us to monitor and further our knowledge in land use/land cover dynamics and its associated impacts (Chakraborty et al., 2009; Deka et al., 2014; Sarma et al., 2016) with greater ease as compared to the conventional ground mapping method, which is time-consuming and labor-intensive (Parveen et al., 2018).

As per the report of Meyer & Turner (1992), from 1700 –1980, land under cultivation was estimated to have increased by 466% globally, whereas closed forest cover decreased by 15.1%, and forest and woodland cover decreased by 14.9% from the pre-agricultural period to 1983. Meanwhile, according to Ramankutty & Foley (1999), on a global scale, nearly 11.4 million km² of forest or woodland and 6.7

million km² of savannas/grassland/steppe have been converted to cropland from 1700–1992. 62% of the earth's total land areas have been transformed from natural vegetated land cover to cropland and urban built-up areas (Afuye et al., 2024). The pattern of land use change, together with people's consumption behavior and productive activities, is responsible for the loss of a significant portion of the world's tropical forests (Baidoo & Obeng, 2023). According to Potapov et al. (2022), from 2000 to 2020, the global net loss of forest land was approximately 1 million km². This loss was mainly concentrated in the global south, with South America experiencing 0.44 million km² loss (which is 5% of forest area in 2000) and South Africa about 0.32 million km² loss (which is 4.6% of forest area in 2000). Asia, Australia, and North America experienced a moderate net reduction in forest area from 2000 to 2020 by 1–2%. Europe was the lone continent with net forest gain by 1.7%. Global cropland area increased by 11.5% from 2000 to 2019, with the largest increment observed in Africa, followed by Asia and South America. India emerged as one of the hotspot countries with a net increase in cropland and built-up land.

A study by Roy et al. (2015) stated that India experienced significant land use change, with approximately 0.10% of its total area, which is about 3,40,932 km² undergoing transformation during the period. A considerable increase was observed in cropland and built-up areas, which expanded from 47.55% to 49.34% and from 1.03 to 1.44%, respectively. Meanwhile, there was a substantial decrease in forest areas (23.25%–22.18%) and wastelands (2.57%–2.27%). Other LULC classes, such as barren land (2.00–2.13%), plantations (2.36–2.38%), and scrublands (5.56–5.65%), exhibited only marginal changes. Expansion of agricultural lands, mining, illegal and legal logging, construction of dams and reservoirs, and shifting agriculture were identified as major drivers of land use and land cover change in India (Roy et al., 2015)

Northeast India holds great ecological importance due to its exceptional biodiversity and diverse ecosystem services, yet it is under intense anthropogenic pressures, with LULC change among the most significant drivers. Over the years, Northeast India has undergone significant shifts in land use and land cover, leading to notable forest fragmentation. However, there is still a lack of accessible, detailed

data and research on how these patterns have changed and what specific factors are driving land use and land cover change in the region. Ritse et al. (2020) conducted land use and land cover mapping stated that in the Eastern Himalayan landscape of Nagaland, focusing on Kohima and Dimapur city for the years 1998, 2008, and 2018. Their study found that rapid urbanization, unplanned development, and poor land management have caused declines in agricultural land and forest areas in both districts. In addition to these drivers, other factors contributing to LULC change included increased fishery ponds, rural to urban migration. They have also observed a reduction in land under shifting cultivation in the areas. A study in Cherapunji, Meghalaya, Prokop (2020), stated that forest area decreased from 18.3% of the total area in 1965 to 17.6% in 2017. Preservation of the forest was observed mostly in the protected areas and narrow, deep-sided valleys. Settlements were observed to expand continuously from 221 ha in 1965 to 408 ha in 2017. Mining areas also increased significantly between 1965 and 2017. Another study conducted in the mid-altitudinal Umngot watershed in Meghalaya showed that increase in settlement and its associated land use pattern caused disturbance in the watershed, and that shifting cultivation is not the major driver of LULC in the area (Chakraborty et al., 2009). In Ukhrul, Manipur, the land covered by settlement and agriculture increased by 1.87% and 0.19% from 1991 to 2020. Whereas, degraded and open forests decreased by 6.12% and 7.47% from 1991 to 2020. A significant increase in dense forest occurred by 11.55% during the period (Shimrah et al., 2021). Few studies on land use/ land cover change and their drivers are available for the state of Mizoram. According to these studies, shifting cultivation, fuel wood collection, timber harvesting, and non-timber forest products (NTFPs) extraction, rural-urban migration, and implementation of the New Land Use Policy (NLUP) are among the most prominent factors influencing land use patterns in the state (Rawat et al., 2017; Sati, 2022).

Despite its significant societal and environmental relevance, our knowledge of how global land use/land cover has changed over space and time remains constrained by lack of comprehensive data (Winkler et al., 2021).

2.2. Microclimate sensitivity to land use change

Key microclimatic variables such as air temperature, relative humidity, and soil quality may vary significantly with land use. Betts (2000) stated that the impact of large-scale land-use alterations on local climate can be as significant as their effects on the global climate. Land use patterns directly influence the physical attributes of land surface such as roughness, albedo, vegetation cover, and leaf area index (Marland et al., 2003). These physical characteristics are among the key factors influencing the regional climate conditions and soil properties. Information on microclimate is vital in monitoring the health, integrity, and sustainability of the land use system. Some of the most relevant microclimatic variables include air temperature, temperature at the substrates, wind direction and speed, air relative humidity, incoming and outgoing radiation (both long-wave and short-wave), precipitation, and soil moisture and temperature (Frenne et al., 2024). Previous studies have firmly established that microclimatic variables are largely modified by vegetation in all the Earth's ecosystems. Topography is another important factor influencing the regional climate; topographical factors affecting microclimate of a region include slope, aspect, and elevation (Hardwick et al., 2015). Hence, the presence of vegetation and its composition are essential in determining the microclimates (Lembrechts et al., 2020). There are certain mechanisms by which trees exert influence on regional climate. The proportion of solar radiation reflected by a surface relative to the total incoming solar radiation it receives is termed as albedo of the surface. Forest generally exhibits low albedo, which indicates that the absorbed solar radiation is higher than the amount reflected (Betts & Ball, 1997). Another significant mechanism that trees influence microclimate is through evapotranspiration, which refers to a combined process of water loss through transpiration from tree leaves and evaporation from soil water and precipitation that has been intercepted by the canopy. This process plays a significant part in both surface and atmospheric cooling, which eventually influences the local climate (von Randow et al., 2004).

Human-induced land use changes, deforestation, and natural disturbances can lead to significant alterations in the patterns and dynamics of microclimatic variables (Chen et al., 1999). Anamulai et al. (2019) compared microclimatic variables among

peat swamp forest and large-scale as well as small-scale oil palm plantations in Peninsular Malaysia. They concluded that the peat swamp forest exhibited cooler and more humid conditions than the oil palm plantations. Peat swamp forest's air temperature was 1.5 to 2.3°C cooler than the oil palm plantation sites. In addition, light intensities and wind speed was also significantly lower in the peat swamp forest than the large scale as well as small scale oil palm plantation sites. These could be largely attributed to the reduction in canopy cover and structural complexity. Similarly, in Jambi, Indonesia, Badu (2016) reported that the temperature in forest and jungle rubber sites were lower than oil palm and rubber plantation sites, whereas relative humidity was observed to exhibit an opposite trend. Furthermore, the seasonal measurements of the different climatic variables revealed that monoculture plantations were drier and less humid across all seasons. Additionally, a strong positive association was observed between canopy cover and air temperature as well as vapor pressure deficit. Their study also concluded that conversion of forest to monoculture plantations result in significant increase in air and soil temperature and vapor pressure deficit, whereas a reduction in relative humidity. Previous studies have reported that forests are instrumental in providing a buffering effect on microclimatic variables. A study in tropical forests, Brazil highlighted the differences in air temperature under fragmented forests, with a more stable temperature inside forests than at forest edges. This could be attributed to the buffering effect of the forest, which reduced the temperature inside the forest by one third of the measured temperature outside. Furthermore, the buffering effect was shown to be more pronounced below-ground than at one meter above the ground. However, the buffering effect was reduced with decreased proximity to forest edges, with reduced buffering capacity observed at 20m inside the forest. Hence, this study identified that forest fragmentation was one of the potential mechanisms through which microclimate can be altered. Key ecological processes such as primary production, nutrient mineralization, and the spread of diseases, insects, and natural disturbances (e.g., fire) are either directly regulated by or empirically linked to microclimatic conditions (Perry et al., 2008). Considering the consequences of microclimatic changes resulting from land use modifications requires serious attention to inform suitable land management practices.

2.3. LULC change implications on soil properties

Variations in soil characteristics are influenced by land use, vegetation, prevailing climate, and the parent materials of the soil (Kenye et al., 2020). Land use-induced soil degradation is more relevant in the tropics, where the combined effects of climate and improper soil management accelerate nutrient loss and reduce soil quality (Delelegn et al., 2017). Soil is an important natural resource that influences ecosystem functioning, sustains biodiversity, and supports the health of plants and animals (Karlen et al., 1997). Therefore, preserving and enhancing soil quality is essential for maintaining ecological sustainability (Delelegn et al., 2017). Deterioration in soil could be a factor of removal of natural vegetation, disruption of soil profile, and utilization of land for cultivation and development (Shekhovtseva & Maltseva, 2015). Conversion of native vegetation to cultivated land decreases soil nutrients and soil organic concentration, while also increases soil compaction (Zucca et al., 2010) and sand content (Biro et al., 2013). In the Shenkolla watershed, south central Ethiopia, assessment of selected soil physical and chemical parameters across different land use systems revealed that the highest value of sand content was highest under the cultivated outfields, followed by the grazing land and forest. Whereas, a reverse pattern was observed for the clay content, with the highest value recorded under native forest (26%). Forest soil was reported to be relatively neutral (pH=7.20) under forest, whereas moderate acidity was reported under the cultivated outfields (pH=5.8). The application of mineral fertilizers in the cultivated outfields resulted in acidification of the soil. SOC, total nitrogen, and available phosphorus were relatively higher in the forest soil compared to the other land use systems, such as grazing land, cultivated outfields, and homestead gardens. In general, soil properties were most favorable under forestland, followed by homestead gardens and grazing areas, whereas the least favorable conditions occurred in intensively cultivated outfields (Bufebo & Elias, 2020). Tellen & Yerima (2018) reported that the conversion of natural forest or savanna exhibited distinct effects on soil physicochemical properties. While certain parameters, such as silt contents, moisture content, pH, total nitrogen, organic matter, organic carbon, available phosphorus, exchangeable bases, and cation exchange capacity were reduced, other parameters like bulk density, exchangeable acidity, electrical conductivity, and sand

content were significantly increased. They also observed that bulk densities under grazing land, farmland, and Eucalyptus plantation were greater than those under natural forest; increase in soil bulk density is largely due to is compaction of soil under intense use. Ayoubi et al. (2011) also reported that in Golestan province, Iran, clearing of natural forest and subjecting the land to tillage practices for 40 years resulted in the reduction of soil organic matter by 71.5%. Cultivation of deforested land led to a 52% decrease in mean weight diameter and a 252% increase in sand content. Conversely, when degraded land was reforested with Cupressus and olive, the SOM increased approximately by 49% and 72% relative to the cultivated land. Land use/land cover conversion from natural forest to cultivated land resulted in increased soil surface compaction, substantial reduction in silt and clay contents, porosity and structural stability, nitrogen, labile and fulvic carbon as well as microbial biomass carbon (Islam & Weil, 2000). Fentie et al. (2020) reported that silt and clay content, available phosphorus, and pH were significantly influenced by land use shifts. Additionally, soil parameters such as total nitrogen and organic matter were significantly influenced by the interaction of both land use and soil depth. The highest content of available phosphorus (10.1 mg/kg) was reported from the natural forest, while the lowest was from grazing lands (4.9mg/kg). Soil total nitrogen was also observed to be the highest in the natural forest at 0.32% and the lowest was from cultivated land at 0.06%. Their findings highlighted that land use change without proper soil quality enhancement measures negatively affected soil quality and significantly reduced the productivity of the studied soil. Guillaume et al. (2015) reported that in Indonesia, about 70% of soil organic carbon (SOC) was lost when tropical rainforests were converted to oil palm and rubber plantations. SOC losses were strongly associated with a significant decrease in biological and chemical components of soil fertility (Guillaume et al., 2016). Land conversion from forest to alternative land use systems often resulted in increased pH levels. Forest soils typically have greater accumulation of litter, and the decomposition process of the accumulated litter tend to reduce pH in forest soil (Salim et al., 2022).

Seasonal variability in soil properties have been established by previous studies. For instance, Piao et al. (2000) examined the response of soil to microbial biomass carbon and observed that soil microbial biomass carbon and atmospheric temperature

exhibited an inverse relationship, with soil microbial biomass carbon content being maximum in winter and minimum during summer. In a semi-deciduous northern tropical forest of Nagaland, soil quality was reported to be highest in the autumn season and lowest during the spring season (Semy et al., 2023). Zhao et al. (2018) studied the temporal variations in soil properties in the Mun river basin, Thailand, and reported significant variation in different soil parameters across seasons. Soil pH, available phosphorus, and SOC were significantly reduced during the rainy season compared to the dry season, where total nitrogen content was found to increase significantly during the rainy season. Yu et al. (2019) reported that in shallow layers of soil (above 2 m), the summer season resulted in a significant decrease in soil moisture content as compared to spring and fall seasons. In the Eastern Himalayas, Lepcha & Devi (2020) reported that the values of all studied soil parameters peaked during the raining season, which showed reduction in summer and winter seasons.

The reduction in fallow period following shifting cultivation has been reported to deteriorate soil properties in Mizoram. The fifteen year old fallow exhibited higher soil quality compared to the ten years old fallow (Wapongnungsang et al., 2021). They observed that burning significantly reduced the levels of soil moisture, microbial biomass carbon, and soil carbon, while other parameters like pH, available phosphorus, and available nitrogen were increased significantly. A study on carbon and nutrients recovery patterns across different ages of shifting cultivation in Mizoram reported that soil organic carbon, available phosphorus, and soil microbial carbon were higher in the natural forest, followed by 15, 5 and 1 years old fallow. The built up of nutrients during the process of ecosystem recovery is responsible for higher nutrient content in the older fallow lands (Ovung & Tripathi, 2021). Hauchhum & Tripathi (2017) stated that the level of soil microbial properties were significantly higher in the longer fallow than in the shorter ones. Majority of the studies in soil properties in Mizoram are focused on shifting cultivation which is the predominant land use system in the state. However, with the decline in shifting cultivation and the growing shift toward settled farming particularly cash crop plantations, there is an increasing need to understand how these changing land uses affect soil properties.

2.4. LULC and tree diversity

Different land use/land cover types are associated with certain tree composition and level of diversity (Jara et al., 2017). Endale et al. (2017) investigated tree diversity and composition in five different land use systems in East Shewa, Ethiopia, and found that homestead exhibited the highest species richness (62), followed by line planting (48), crop land (37), woodlot (29), and grazing land (10). Meanwhile, the highest Shannon diversity index was recorded from line planting (3.1), homestead (3.05), crop land (2.43), grazing land (1.9), and woodlot (1.8). The primary forest in Central Sulawesi, Indonesia supported the highest tree species richness compared to other land use systems, followed by forest gardens, 5-year-old secondary forests, and cacao plantations (Kessler et al., 2005). The higher species richness in forest gardens compared to the other human-modified land use systems could be attributed to their origin from the primary forest. Forest gardens had more trees with larger girths compared to secondary forests, as the latter developed on lands where trees had been completely cleared for cultivation before being allowed to regenerate. The taxonomic composition revealed that trees belonging to Lauraceae, Maliaceae, and Moraceae were significantly reduced in the secondary forests, whereas those belonging to Asteraceae, Ulmaceae, and Urticaceae were abundant. In general, secondary forests were characterized by pioneer, fast-growing species. In Pyin O Lwin, Myanmar, Helen et al. (2019), carried out a tree diversity and richness study across four different urban green spaces and found that monasteries (73) recorded the greatest number of species, followed by botanical garden (32), coffee farms (12), and city golf course (10). In northern Borneo, the mean species richness between natural forest and logged forest was comparable, with no statistically significant difference observed between them. However, both forest types differed significantly from old and young secondary regrowth, as well as from young and old rubber forests. Furthermore, the natural forest was reported to outperform all other land use types in terms of mean Fisher's α diversity index (Labriere et al., 2015). A study in Ghana by Anglarea et al. (2011), reported that fallow land supported higher species richness than cocoa plantations and natural forest. Meanwhile, the stem count was highest in the natural forest than

in other land use systems. Their study indicated that species richness and stem density are strongly influenced by land use.

Tree density and basal area are key parameters for understanding the population structure and functional dynamics of a forest ecosystem (Fatehi et al., 2017). The density of a species is typically used to determine the abundance and distribution of a species in a specified area. Meanwhile, basal area helps to determine the competition among trees per unit area, the successional stage, and habitat quality. Land cover and management practices are important factors influencing density and basal area (Kayombo et al., 2022). In the northeastern part of Madagascar, Osen et al. (2021) reported that old growth forest exhibited higher basal area than forest fragments and vanilla agroforestry. Besar et al. (2020) stated that, in tropical Malaysia, natural forest showed the highest stand density at 475 trees/ha compared to the plantation sites, recording less than 50% of the natural forest. In addition, the agroforestry system, combining oil palm (27 years) and agarwood (7 years) recorded higher tree density than the monoculture plantations of oil palm. They further emphasized that the highest tree density in the natural forest stands reflected the random distribution pattern of trees in natural forests. Meanwhile, the tree density in both agroforestry systems and monoculture plantations was largely determined by planting distances implemented at the site. In agricultural landscapes, an increase in tree cover was found to support higher diversity of plants and invertebrate and significantly enhance ecosystem functions that sustain ecosystem services (Hailu et al., 2021). Quadrat sampling was the first commonly used technique for quantitative assessment of plant community. Using the data obtained through quadrat methods, the frequency, density, and dominance of species are determined. This information is essential in order to classify plant/forest communities based on their composition and structure. The most commonly used quadrat size for sampling includes 10m × 10m, or 20m × 20m quadrat for trees, 5m × 5m for shrub, and 1m × 1m for herbs. Nevertheless, the location, size, and number of quadrat largely depend on the research aim and the investigator's decisions (Sudia, 1960).

A study carried out by Saikia et al. (2013) at Nameri Tiger Reserve in Assam, India, assessing LULC and fragmentation concluded that from 1973 to 2007, there

had been a sharp decrease in dense forest cover, while the open forest cover increased marginally and that encroachment by small farmers had been the major driver for these changes. It is evident that Land use/land cover changes influence the vegetation of an area (Ramírez-Marcial et al., 2001; Verstegen et al., 2019). According to Tesfaye et al. (2014), due to Land use/land cover change in Gilgel, Tekeze, Northern Ethiopia, there is significant variation in vegetative structure and composition across the different land use types. Their study also revealed that shrub-bush land has higher species diversity than natural forest and plantation areas. This is in contrast to the study carried out by Kessler et al. (2013) at Central Sulawesi, Indonesia, where they revealed that tree diversity is the highest in primary forest, followed by secondary forest, forest garden, and cacao plantations. It was also reported that while Lauraceae, Meliaceae, Euphorbiaceae were dominant in primary forests, Urticaceae, Ulmaceae, and Euphorbiaceae were dominant in secondary forest; meanwhile, the dominant families in forest garden were Euphorbiaceae, Myristicaceae and Rubiaceae and the cacao plantation had almost exclusively cacao trees. However, another study conducted by Paré (2008) on land use dynamics and its effect in Southern Burkina, West Africa, showed that there is no significant difference in tree diversity across the different land cover types, contrary to expectation of high diversity in protected forest. Ramírez-Marcial et al. (2001) stated that change in land use patterns have negative impacts on tree diversity, especially for understory trees. Verstegen et al. (2019), developed land use change projections and their impact on carbon stock and biodiversity up to 2030 in Indonesia based on LULC change map from 1990-2009 under four contrasting LULC change scenarios-limited and unlimited land development, restricted and unrestricted zoning. Their study projected a significant decrease in mean tree species richness by 3% (385–375) under the two scenarios with limited development. However, under the other two unlimited development scenarios the projected decrease in mean species richness varies, with unlimited development-restricted zoning having a projected decrease in mean species richness by 10% (from 385–345) and projected decrease under unlimited development-unrestricted zoning is from 385–230 (40%).

Although studies on tree diversity have been conducted in Mizoram, they remain relatively limited in scope and number. Nohro & Jayakumar (2020) investigated tree species composition and diversity in the Pala wetland reserve forest of Mizoram and recorded 65 tree species under 57 genera and 31 families. The basal area was calculated at 59.54m²/ha, while tree density was estimated at 552.8 trees/ha. In an undisturbed and disturbed tropical semi-evergreen forest stands in Lunglei, Mizoram, Lalfakawma et al. (2010) recorded higher tree species richness in the undisturbed stand (32) than in the disturbed stand (17). Singh & Sahoo (2021) stated that in the overall tree species richness in traditional home gardens is greater than shifting cultivation fallows in Aizawl district, Mizoram. They also reported that size as well as age of home gardens and age of the shifting fallows exert significant influence on the tree diversity and community attributes such as tree density and basal area. Age of the home garden was inversely related to species diversity whereas an opposite pattern was observed the shifting fallow. In addition, several studies from Mizoram focused on the fallow age effects on tree species. For instance, Hauchhum & Singson (2020) reported that tree species richness was highest in the 10 year old fallow, followed by 30 year old, 20 year old, and 5 year old fallows. Basal area, however, was found to increase with fallow age. The species composition in different shifting cultivation fallows revealed the dominance of pioneer early successional to mid-successional species such as *Albizia chinensis*, *Macaranga indica*, and *Derris robusta*. Existing literature have established that disturbance and land use pattern have significant influence on stand diversity, composition, and structure. These influences are expected to be more pronounced in ecologically sensitive and biodiversity-rich regions like Mizoram, therefore, studies addressing information gaps are required in the state.

2.5. Land use change and human wildlife conflict

Hansen et al. (2004) reported that for the past few decades, there has been rapid human population growth and intensified land use around several protected areas based on their satellite-based change analyses. Jones et al. (2009) stated that the natural resources and ecological processes within a protected area may be substantially influenced by land use/ land cover change surrounding the protected

area. The type of land use surrounding protected area is determined by the socio-economic settings; for example in socio-economic settings where high density of human populations is dependent on local resources, the most common form of land use are fuel-wood and Non-Timber Forest Produce (NTFP), forest grazing, poaching or hunting in a forest ecosystem while those with low density of human populations have low intensity use of forest products (Defries et al., 2007). Changes in cropping pattern with its associated land use change surrounding a protected area were found to intensify and increase incidents of human-wildlife conflict in Gir National Park, India. Groundnut and millets, which were once cultivated, were replaced with sugarcane and mango, as these crops provide a suitable habitat for wildlife (Vijayan & Pati, 2002). Fernando et al. (2005), in their study on the perception and pattern of human-elephant conflict in Sri Lanka suggested that the pattern of land use and agricultural practices are the determinants of human-elephant conflict. In the mountain area of Simao, China, in proximity to Xishuang Banna Nature Reserve, a group of 19-24 Asian elephants is responsible for large-scale crop and property damage. The conflict arises from the degradation and fragmentation of the elephant's habitat, as a result, the elephants resort to raiding fields and villages in search of food (Distefano, 2003).

Understanding the nature and extent of human-animal conflict and the perception of people towards wildlife is a key to achieving conservation and management goals. Dutta et al. (2015) reported that Wild boar (*Sus scrofa*), Golden jackal (*Canis aureus*), Rhesus Monkey (*Macaca mulata*), and Civet (*Viverricula indica*, *Paguma larvata*, *Viverra zibetha*) are the animal species involved in human-wildlife conflict in the forest villages of Barrack Valley, Assam. In Mallapuram District, Kerala, five animal species-Asian elephant (*Elephas maximus*), Wild boar (*Sus scrofa*), Indian crested porcupine (*Hystrix indica*), Bonnet Macaque (*Macaca radiata*), and Hanuman langur (*Semnopithecus entellus*) are considered problematic species (Jayson, 2016). People who are directly affected by wildlife tend to develop a negative attitude towards wildlife and concerned authorities (Parry & Campbell, 1992), whereas people who derive benefit from wildlife and its management generally have positive attitude towards wildlife (Western, 1982). Community members suggested that tolerance would increase if they derive income from the

conservation of wildlife (Lindsey et al., 2007). Provision of financial compensation for losses due to wildlife improves attitude and tolerance (Nyhus et al., 2005). Mordi (1991) found that education made people more conservation-conscious and less utilitarian in their attitudes towards wildlife. Potential strategies for mitigating human–wildlife conflicts were also dependent on the type of land use practiced. Cultivators in Amboseli area, Kenya preferred fencing and culling as solutions. Those who only raised livestock favored the translocation of wildlife into parks, as well as compensation for livestock depredation. Fencing human developments (e.g., farms) was often mentioned as a potential strategy followed by translocation of wildlife away from the group ranch in protected areas. Methods used for protecting crops were considered to be less effective for controlling large herbivores (especially elephants) and primates, but were thought to be effective for controlling small- to medium-sized herbivores (Okello, 2005). Jayson (2016) reported that beehive fencing, biorepellent, and yellow clothes were employed to mitigate crop raiding by wildlife in Mallapuram district, Kerala. These methods were found to reduce the problem to a certain extent; nevertheless, better strategies could be employed for efficient management and mitigation of conflict. A total amount of Rs.170.069 lakhs was given as Wildlife Damage Compensation from 2006-2007 to 2013-2014 by the Govt. of Mizoram. Of this, Rs.84.089 lakhs was spent to compensate for loss that took place within the Protected Areas. During this eight-year period, human-animal conflict resulted in the death of 21 persons and an injury to 35 individuals, 20 domestic animals (mostly cattle) were killed and more than 3000 cases of crop damage were reported to the Department of Environment, Forest and Climate Change (Lalzidinga, 2015).

In summary, earlier research has shown that alterations in land use and vegetation cover can significantly influence local microclimates, soil characteristics, tree diversity, and the extent of human-wildlife interactions. Despite these valuable insights, most studies have concentrated on different regions, offering a limited understanding of how such factors vary across specific land-use systems in the context of Mizoram. Therefore, the present study aims to bridge this gap by assessing tree diversity, habitat characteristics, and the implications of human activities within

the Dampa Tiger Reserve. This approach will help in understanding the ecological patterns and processes governing forest dynamics and conservation priorities in the region.

3.1. Description of the study site

Mizoram

Mizoram is a state in India, located in the northeastern corner of the country. The state shares its boundary with three Indian states and two countries. It is bounded by Assam to the north, Manipur to the northeast, Tripura to the northwest, Bangladesh to the west, and Myanmar to the east and west. Aizawl is the state capital and is located in the north-central part of the state. It covers an approximate area of 21,081 km sq. which is about 0.641% of the India's total land area. According to the 2011 census, the state's population is 1.09 million and constitute about 0.09 % of the country's population.

The mountains in Mizoram run from north to south in a series of compact parallel ridges. The western ranges are steep while the eastern ranges are somewhat gentler. The hills in the west have average height of 1000 meters and that of the eastern side is 1300 meters. The state's geology is dominated by limestone, sandstone, and shale, while the soil is acidic with texture ranging from sandy to clayey, rich in organic carbon but low in nutrients. Mizoram has a number of rivers, streams, and brooks flowing between the mountain ridges. The major rivers in the northern part, flowing northwards are the Tlawng, the Tuirial, the Tuivai and the Tuiruang (Barak) and its tributaries. The Chhimtui (Koladyne) with its four major tributaries- the Mat, the Tuichang, the Tiau, and the Tuipui, and the Khawthlangtui (Karnapuli) constituted the southern flowing rivers. The state experiences humid tropical climate, with moderate temperature. The winter season is mild with temperature ranging from 11°C to 20°C, the higher altitude can experience colder days. The warmer season has average daytime temperature rising to 30°C or above especially in the lowlands. Rainfall in Mizoram is significantly influenced by the southwest monsoon with the state receiving heavy rainfall during the period. The annual precipitation ranges from 2000mm to 3500mm, mostly falling during the monsoon season. The humidity levels are high especially during the monsoon,

sometimes exceeding 90%. A gradual decrease in humidity is observed in winter, providing drier conditions.

As per the report of Forest Survey of India, 2023, Mizoram has 85.34% of its total geographical area under cover, which is 17,990.46 km² (Forest Survey of India, 2023) Open forest constitutes 43.14%, moderately dense forest 40.96%, and very dense forest covers 1.24% of the total area. Based on the Champion and Seth forest classification, Mizoram's forests are categorized into four Type Groups, which are further classified into six forest types. The tropical wet-evergreen, Montane sub-tropical forest, temperate forest, bamboo forest, and quercus are the major forest types in Mizoram. Located within the Indo-Burma biodiversity hotspot, the state of Mizoram is home to a wide diversity of flora and fauna.

Dampa tiger reserve

The site selected for the study is Dampa Tiger Reserve, situated in Mamit district, in the western part of Mizoram. It lies between 23°20'– 23°4' N and 92°15' – 92°30'E and has an elevation ranging from 200m – 1100m above mean sea level (Figure 3.1.1). The mean annual rainfall is reported as 2150mm, received rainfall mainly during the southwest monsoon period, from May to October. It experiences humid sub-tropical climate and recorded a mean annual temperature of 12°C – 35°C. The weather is warm and pleasant throughout the year, with moderate or chill weather prevailing at the higher altitude during winter. Dampa was declared as a wildlife sanctuary in the year 1985, it was then re-notified as a tiger reserve in 1994 to be the largest protected area in the state. Covering a total area of 998 km², the reserve is delineated into two management and conservation zones- the core zone and the buffer zone. The strictly protected core zone encompasses an area of 500 km², where any anthropogenic activities are prohibited without prior authorization. Meanwhile, the multi-use buffer zone extends over 448 km², where anthropogenic land use constitutes the pre-dominant land cover. Dampa landscape is composed of undulating hills, deep valleys, and perennial rivers (Teirei, Saza, Keisalam, and Seling) and small streams that flow inside the area.

The reserve is home to a rich diversity of flora and fauna; and falls under the Indo-Burma biodiversity hotspot. Owing to its critical significance in the

conservation of birds and their habitat, Dampa TR was identified as an Important Bird Area (IBA) in 2004. Raman (2001) recorded 138 bird species from the Dampa landscape, while 112 species was recorded by Mandal & Raman (2016). The bird community in DTR is represented by species such as the Great Hornbill, Oriental Pied Hornbill, Grey Peacock Pheasant, Red Jungle Fowl, Wreathed Hornbill, Red-headed Trogon, Blue Pitta, Mountain Imperial Pigeon, Puff-throated Babbler, Yellow-bellied Warbler, Black-browed Leaf Warbler, and others. The area provides an excellent example of the avifaunal diversity of the Indo-Chinese Moist forest. Tiger, Clouded Leopard, Leopard Cat, Marbled Cat, Asiatic Golden Cat, and Leopard are among the key felid species from Dampa. It also supports one of the highest numbers of primate species recorded in India, including the Western Hoolok Gibbon, Phayre's Leaf Monkey, Capped Langurs, Rhesus Monkey, Assamese Macaque, Stump-tailed Macaque, and Bengal Slow Loris. Other notable mammals include Sambar, Asian Elephant, Binturong, Malayan Sun Bear, Indian Palm Civet, Crab Eating Mongoose, and Indian Jackal. Studies on herpetofaunal diversity recorded 28 species of amphibians (Lalremsanga et al., 2021) and 22 species of lizards (Solanki, 2015). The natural vegetation of Dampa encompasses a diverse range of habitats from grassland to bamboo breaks, open forests to dense, primary undisturbed forests. Forest assemblage is characterized by species such as *Mesua ferrea*, *Schima wallichii*, *Castanopsis tribuloides*, *Michelia champaca*, *Gmelina arborea*, *Sterculia villosa*.

The administration of Dampa Tiger Reserve falls under the jurisdiction of the Field Director's Office at West Phaileng, with management carried out through the Teirei forest range and Phuldungsei forest range. There are about 15 villages in the buffer zone of the reserve, with habitants from the Mizo, Bru, and Chakma community. Farming constitutes the main source of livelihood for the local community. Historically, the traditional shifting cultivation, also known as jhum or lo was the most dominant form of agriculture, but this is slowly replaced by settled agriculture. As a result, the DTR landscape is a mosaic of monoculture plantations of teak, oil palm, rubber, areca nut, mixed plantations of horticulture

plants, jhum sites, and secondary successional vegetation of varying ages, and settlements.

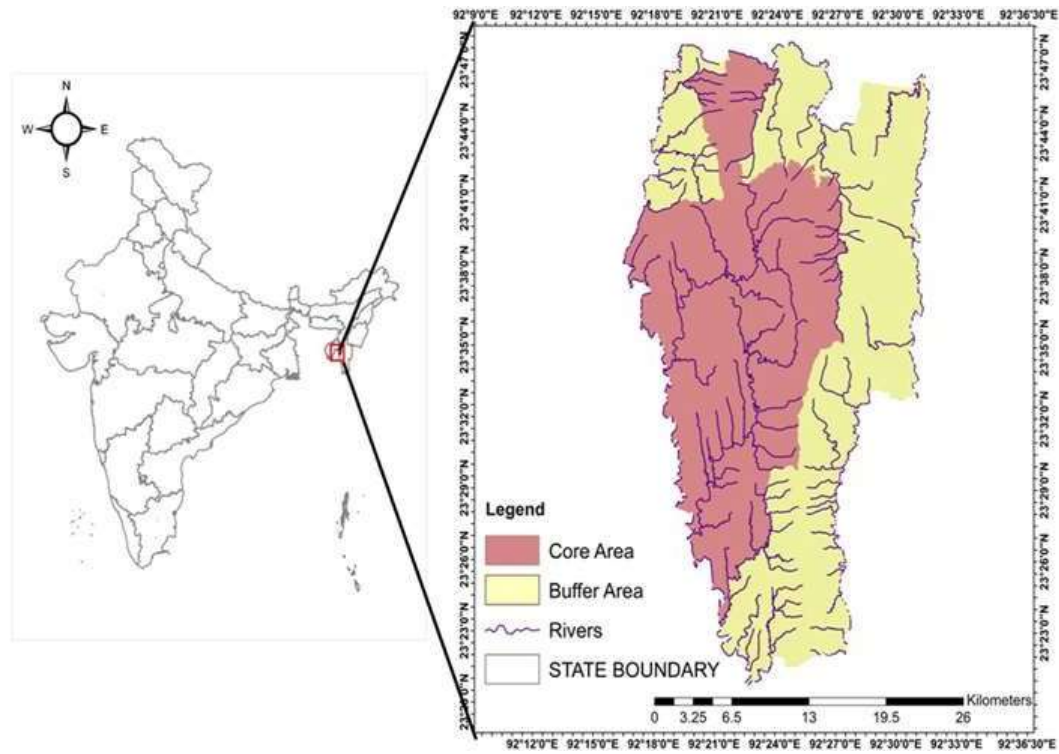


Figure 3.1.1 Map showing the location of DTR

3.2. Methods

3.2.1. Land use/land cover mapping and change detection

Land Use/Land Cover (LULC) classification was conducted using the Google Earth Engine (GEE) platform, utilizing Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) Surface Reflectance data for the dry season periods (February–April) of 2011 and 2021, respectively. To reduce atmospheric effects and seasonal variability, a median compositing approach was applied to the filtered image collections. This produced seamless, cloud-free mosaics and effectively reduced transient noise and cloud cover. A critical pre-classification masking strategy was implemented to resolve specific spectral confusions inherent to the study area's topography, specifically, the high spectral similarity between

exposed shifting cultivation (*Jhum*) lands and impervious built-up surfaces, as well as the overlap between water bodies and topographic shadows. To address this, non-vegetated features (Built-up and Water) were masked prior to classification using the Dynamic World V1 dataset. For the 2021 epoch (Brown et al., 2022), the concurrent 2021 Dynamic World data was utilized; however, given that the Dynamic World record is unavailable prior to 2015, the 2015 Dynamic World product (<https://dynamicworld.app/>) was employed as the nearest temporal proxy to generate the Built-up and Water masks for the 2011 analysis. The remaining pixels were classified into Forest and Jhumland categories using the Random Forest (RF) machine learning algorithm, parameterized with 500 decision trees and trained on standard visible and infrared spectral bands. The model's performance was evaluated using a split-sample validation approach, where 30% of reference samples were reserved for testing, generating confusion matrices (PA; Producer's Accuracy, AU User's Accuracy) to derive Overall Accuracy (OC) and Kappa coefficients (KC) for both study periods.

Selection of land use systems for assessing microclimate, soil characteristics, and tree diversity and community characteristics

Six major land use systems were further selected for the assessment of microclimate, soil characteristics, and tree diversity and community characteristics (Photo plate 1). They are (i) Natural forest (NF) - Located within the core zone DTR with minimal anthropogenic disturbances.

(ii) Secondary forest (SF) - Located within the buffer zone of DTR. SF consists of regenerating/ disturbed forest which has undergone anthropogenic disturbances in the past in the form of selective logging or shifting cultivation.

(iii) Current Jhum (CJ) - This represents an active shifting cultivation area where vegetation is cleared and burned as a preparatory phase for agriculture. Rice, local vegetables, maize, and ginger are the major crops included in jhums. The land is cultivated for a few years and abandoned as jhum fallow to allow natural regeneration.

(iv) Oil palm plantation (OP) - This consists of a monoculture oil palm (*Elaeis guineensis*) plantation, with only occasional native trees scattered within the stand.

Oil palm plantations were established in the area following the implementation of the New Land Use Policy (NLUP) in an effort to eradicate jhum cultivation in the state.

(v) Teak plantation (T) – This is characterized by monoculture plantation of teak (*Tectona grandis*) trees, with a few native trees scattered within the stand.

(vi) Areca nut plantation (AN) – This site comprises a monoculture areca nut (*Areca catechu*) plantation, with only few trees retained within the stand.



Natural forest within DTR core zone



Secondary forest within DTR buffer zone



Current Jhum within DTR buffer zone



Oil palm (*Elaeis guineensis*) plantation



Teak (*Tectona grandis*) plantation



Areca nut (*Areca catechu*) plantation

Photo plate 1: Photographs of study sites

3.2.2. Microclimate

To understand the microclimate, ambient temperature and relative humidity was determined using Thermo Hygrometer.

Statistical analyses

All statistical analyses were conducted using R software, (version 4.3.0; R Core Team, 2022). The Shapiro-Wilk test was used to assess the normal distribution of data, and Levene's test was used to evaluate homogeneity of variances. Non-parametric data were analyzed using Kruskal-Wallis rank sum tests, followed by Dunn's post hoc test with Bonferroni correction when significant. For data that were normally distributed but exhibited unequal variances, Welch's ANOVA was applied, followed by Games-Howell post hoc tests. Parametric data (normal distribution and equal variances) were assessed using one- way ANOVA with Tukey's post hoc test.

3.2.3. Soil analysis

Soil samples were collected from two different depths (0–10 cm and 10–20 cm) randomly from each site considering three seasons namely pre-monsoon (January – April), monsoon (May – August), and post-monsoon (September – December) seasons. Randomly collected soil samples were made into composite samples by mixing in their respective soil depth. The depth wise soil samples were also collected to study the bulk density. Soil temperature was measured on site using soil thermometer. The collected soil samples were properly sealed in bags, labeled, and brought to the laboratory for further analysis. In the laboratory, samples were rid of any debris, stones, rubbles, roots and other plant materials. Fresh soil samples were used to determine moisture content and pH; then, the rest of the samples were air-dried and passed through a 2mm and 0.5mm sieves for the analysis of the other parameters (Photo plate 2).





Photo plate 2: Soil sampling and analysis

Soil Moisture Content (SMC) (%)

The gravimetric method described by (Allen, 1974) was adopted to estimate the soil moisture content. According to this method, 10 grams of freshly collected soil sample was taken in a crucible and then dried in a hot air oven for 24 hours. The percent moisture content was then determined using the following formula:

$$\text{Moisture Content (\%)} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

W_1 = Initial Weight

W_2 = Final Weight

Bulk Density (BD) (g cm^{-3})

Anderson & Ingram (1994) was followed to determine soil bulk density. Soil surface was cleared of plant debris and other materials; this was followed by driving a soil corer (a metal tube) of 5.5 cm diameter into the soil at the corresponding depth of the soil. Excess soil from the end of the corer was trimmed off using a knife. The collected samples were stored in bags and brought to the laboratory for drying. Samples were dried in a hot air oven at 105 °C till constant weight was achieved. Further, the soil bulk density was determined using the following formula:

$$\text{Bulk Density } \left(\frac{\text{g}}{\text{cm}^3} \right) = \frac{W_1 - W_2}{V}$$

Where,

W_1 = Dry weight of the soil

W_2 = Weight of the metal tube

V = Volume of the corer

Water Holding Capacity (WHC) (%)

The WHC of the soil was determined following Keen box method (Piper, 1942). The perforated keen box was prepared by lining the bottom of the box with Whatman filter paper no. 42. The weight of the box with the filter paper was taken and recorded. Air-dried soil samples were sieved using a 0.5mm sieve and placed in the keen box. The weight of the box with the filter paper and soil sample was taken. The box was then placed in a petri plate containing water and left to stand overnight for saturation purposes. The final weight of the box was then recorded and the water holding capacity was calculated using the following formula:

$$\text{Water Holding Capacity (\%)} = \frac{W_3 - W_2}{W_2 - W_1} \times 100$$

Where,

W_1 = weight of the box + filter paper

W_2 = W_1 + oven dried soil (105 °C).

W_3 = W_2 + absorbed water

Soil texture

Soil texture was determined following Allen (1974), using Bouyoucos hydrometer. 50 g of soil (< 2.0mm) was taken in a suitable container; 25 ml of dispersing solution (5% Sodium hexametaphosphate) and 200 ml of water was added and stirred continuously using high speed stirrer. After the shaking process, the suspension was transferred to a 1000 ml cylinder and water was added up to the mark. The suspension was then stirred for 1 minute with a glass rod, the first reading was taken by dipping the hydrometer and recording the value at 40 seconds. The second reading was taken after 2 hours from the first reading. The temperature of the

suspension was recorded at each reading. Blank was prepared following the same procedure. The percent silt, clay, and sand were calculated using the following formulae:

$$\text{Sand (\%)} = \frac{\text{Corrected hydrometer reading at 40 secs.}}{\text{Weight of sample}} \times 100$$

$$\text{Clay (\%)} = \frac{\text{Corrected hydrometer reading at 2 hrs}}{\text{Weight of sample}} \times 100$$

$$\text{Silt (\%)} = 100 - (\text{Sand \%} + \text{Clay \%})$$

The texture of the soil was determined with the help of soil texture triangle (Figure 3.2.1)



Figure 3.2.1 Soil texture triangle

pH

Soil acidity or alkalinity is determined by the amount of hydrogen or hydroxyl ions present. Soil pH is the degree of H^+ ion activity of soil water system. It specifies whether the soil is acidic, neutral, and alkaline in reaction. The pH of the soil was measured using electronic digital pH meter. Sample was prepared by taking 10 g of soil in a 100 mL beaker to which 50mL of distilled water was added. The soil water suspension was stirred at regular intervals for 30 minutes and pH was recorded.

Soil Organic Carbon (SOC)

Walkley and Black's rapid titration method was used to determine soil organic carbon (Walkley & Black, 1934). 0.5 g of air-dried was taken in a 500 ml conical flask and 10 ml of 1N potassium dichromate ($K_2Cr_2O_7$) and 20 ml concentrated H_2SO_4 were added. The contents were mixed thoroughly by swirling the flask gently and were allowed to stand for 30 minutes. This was followed by the addition of 200 ml of distilled water and 10 ml of ortho-phosphoric acid (H_3PO_4). Then, 1 ml of diphenylamine indicator was added. Finally, the content was titrated against 0.5 normality ferrous ammonium sulphate ($Fe (NH_4)_2(SO_4)_2 \cdot 6H_2O$) solution. The end point was determined when colour of the solution changed from violet through blue to green. A blank titration was also conducted. The content of organic carbon present in the soil was determined using the following formula:

$$\text{Organic Carbon (\%)} = \frac{N \times (B - T) \times 0.003 \times 100}{\text{Weight of sample}}$$

Where,

N = Normality of ferrous ammonium sulphate ($Fe (NH_4)_2(SO_4)_2 \cdot 6H_2O$) solution

B = Blank reading (ml)

T = Sample reading (ml)

Soil Organic Matter (SOM)

Soil organic matter was determined through multiplication of SOC concentration by the factor 1.724 (Jackson, 1964).

$$\text{Soil Organic Matter (\%)} = \text{SOC} \times 1.724$$

Available Nitrogen (AN)

In soil, nitrogen is found as nitrate, nitrate nitrogen, and organic nitrogen. A large percentage (90%) of soil nitrogen is present in combination with organic matter. The easily mineralizable nitrogen present in the soils is known as available nitrogen. The nitrogen mineralization test provides a measure of the sum of nitrogen that may become available through microbial decomposition of the total organic nitrogen present. Kelplus kjeldahl was used for determination of soil available nitrogen. 5g of air dried soil sample was taken in an 800 ml Kjeldahl flask and loaded in the distillation unit. 25 ml each of potassium permanganate (0.32%) and sodium hydroxide (2.5%) solution were automatically added to the flask by the distillation unit program. The sample was heated steadily and the liberated steam was absorbed in 20 ml of 2% boric acid containing mixed indicator kept in a 250 ml conical flask. The pinkish colour of the boric acid solution turned green with the absorption of ammonia. Nearly 150 ml of distillate was collected in about 10 minutes. Finally, the distillate was titrated against 0.02 N H₂SO₄ with the end point determined when the green color of the distillate changed to the original shade (pink). Blank sample was run simultaneously. The titrated readings were recorded and the available nitrogen content was calculated as follows:

$$\text{Available Nitrogen } \left(\frac{\text{Kg}}{\text{ha}} \right) = \frac{R \times N \times A \times W}{\text{Sample weight} \times 1000}$$

Where,

R = Sample reading – Blank reading

N = Normality of acid

A = Atomic weight of Nitrogen

W = Weight of one hectare of soil

Available Phosphorus (AP)

Phosphorus is an essential plant nutrient and is present in different forms. Estimation of soil available phosphorus was carried out following the method

described by Olsen et al. (1954). 2.5g of air dried soil was taken in a 150ml conical flask and 0.5g of activated charcoal was added. Then, 50 ml of 0.5M NaHCO₃ was

added and placed in a mechanical shaker for 30 minutes. Similar procedure was run for blank simultaneously. The suspension was then filtered through Whatman filter paper no.40. In a 25ml volumetric flask, 5 ml of the aliquot was extracted and acidified with 5N H₂SO₄. A small quantity of distilled water was added followed by 4ml of reagent B, and the volume was made up to the mark with distilled water. Reagent B was prepared by dissolving 1.056g of ascorbic acid in reagent A (a solution of ammonium paramolybdate and potassium antimony tartrate in 1ltr of 5N H₂SO₄). Calibration curve from the reading of standard solution was prepared by running series of prepared standard phosphate solution in UV spectro-photometer. The intensity of the blue coloration was subsequently measured at a wavelength of 600 nm. The amount of available phosphorus was determined using the formula:

$$\text{Available Phosphorus } \left(\frac{\text{Kg}}{\text{ha}} \right) = \frac{R \times F \times 50 \times 2.24}{5 \times 2.5}$$

Where,

R = Absorbency

F = Concentration of P for absorbency A / Absorbency from standard curve

Available Potassium (AK)

The available potassium includes both exchangeable and water soluble potassium and is determined by extracting soil with neutral and normal ammonium acetate solution using flame photometer (Allen, 1974). 5g of soil sample was taken in a 100ml conical flask and 25ml of 1N NH₄O Ac solution was added. The content was shaken in a mechanical shaker for 5 minutes and filtered through Whatman no. 1 filter paper. Before running the samples, the flame photometer was calibrated using standard potassium solution. The potassium extract was then measured using flame photometer after calibration. The soil available potassium was determined by incorporating the reading into the following formula:

$$\text{Available Potassium } \left(\frac{\text{Kg}}{\text{ha}} \right) = \left(\frac{1}{5} \times 25 \times R \right) \times 2.24$$

Where,

R = Sample reading

Statistical analysis

The seasonal mean values ($\pm$ SD) from the two soil depth (0–10 cm and 10–20 cm) were taken to estimate the seasonal difference among the soil physicochemical parameters by analysis of variance (one-way ANOVA) with Tukey's HSD at $p < 0.05$ level. Pearson correlation coefficient was used to determine the significant correlations between the soil physicochemical parameters. Both the statistics were performed using statistical software SPSS (version 26) and R (version 4.3.0; R Core Team, 2022).

Evaluation of Soil Quality Index (SQI)

Selection of MDS

The additive and weighted methods outlined by Marzaioli et al. (2010) were used to determine the seasonal soil quality index. Evaluation involved three steps namely- (i) the selection of indicators among the soil parameters as Minimum Data Set (MDS) that could best represent the soil function (ii) scoring of these indicators, and (iii) integration of the scores to compute the SQI. The Principal Component Analysis (PCA) was employed to consider parameters as MDS that will best characterize the soil function. Principal components (PCs) with eigenvalue ≥ 1 were selected following the condition that they contribute to least 5% of variation in the data (Mandal et al., 2008). Variables that fall within 10% of the highest factor loading were selected under each PC to constitute the MDS. In order to avoid redundancy and check for correlations between variables, Pearson's correlation analysis was conducted when more than one indicator was retained under a component. In case of highly correlated variables ($r > 0.7$), the variable with the higher factor loading was included in the MDS.

Scoring of indicators

The variables selected for MDS were transformed into dimensionless score ranging from 0 to 1 using linear scoring function (Liebig et al., 2001). They were then grouped into – “good” or “bad” based on their influence on soil function. When an increase in a particular parameter result in soil quality improvement a “more is better” scoring curve was applied, and a “less is better” curve was used for parameters that are considered bad for the soil. Scoring of “more is better” parameters was done by diving each observation by the highest value, such that the highest observation has a score of 1. Meanwhile, “less is better” indicators were scored by calculating the ratio of each observation over the lowest value such that the lowest observation has a score of 1 (Vasu et al., 2016).

Determination of SQI

The additive and weighted SQI were calculated using the following equations:

$$\text{Additive SQI} = \sum_{i=1}^n \frac{S_i}{n}$$

$$\text{Weighted SQI} = \sum_{i=1}^n W_i S_i$$

Where

S_i = the indicator score,

n = the number of parameters selected in the MDS

W_i = the weighing factor derived from the PCA result

3.2.4. Phytosociological assessment

Sampling

Phyto-sociological sampling was conducted in both the core and buffer zones of the DTR. For sampling, 20m × 20m quadrats were laid in each zone following standard quadrat method keeping the physiographic conditions in account (Curtis & McIntosh, 1950). Within each plot, all trees with a Girth at Breast Height (GBH) measuring > 30cm were recorded, identified at a species level, and their girth measured at 1.37m from the ground using a measuring tape. Buttressed-trees were measured above the buttress, while trees on slopes were measured at the standard

height above the ground on the uphill side of the tree. Trees that are bifurcated below the breast height were measured separately (Photo plate 3).



Photo plate 3. Photographs of field sampling

Quantitative analysis

Quantitative characters of the community such as spatial distribution, stand density, basal cover, and importance value index (IVI) were calculated following Misra (1968), Mueller-Dombois & Ellenberg (1974) and Magurran (1988). The quantitative characters such as frequency, abundance, and density were calculated according to the following formula:

Frequency: Frequency of an individual species refers to the degree of dispersion in an area and is expressed in terms of percentage:

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which a species occur}}{\text{Total number of quadrats studied}} \times 100$$

All the species were classified into Raunkier's frequency class to comprehend the spatial dispersion pattern of each individual species.

Density: It refers to the number of individuals belonging to a species in a unit area and is calculated using the formula:

$$\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied}}$$

Abundance: It is the number of individuals of a particular species present in a given area and is determined using the formula:

$$\text{Abundance} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats in which a species occur}}$$

Basal Area: The basal area of an individual tree is calculated using the formulae:

$$\text{DBH} = \frac{\text{Girth}}{\pi}$$

$$\text{Basal Area (m}^2\text{)} = \frac{\pi \times \text{DBH}^2}{4}$$

Important Value Index (IVI): In order to express the ecological success and subsequent dominance of a species in an area, IVI is used. The calculation involves summing the values of relative frequency, relative density, and relative dominance (Misra, 1968).

Relative Frequency: It refers to the distribution of a species in relation with all the other species and is calculated as:

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all the species}} \times 100$$

Relative Density: It is the proportions of individuals of a particular species relative to the total density of all the species and is determined using the formula:

$$\text{Relative Density} = \frac{\text{Density of a species}}{\text{Total density of all the species}} \times 100$$

Relative Dominance: It is a reflection of how much space a species occupies and is calculated as:

$$\text{Relative Dominance} = \frac{\text{Basal area of individuals of a species}}{\text{Total basal area of all the species}} \times 100$$

IVI = Relative Frequency + Relative Density + Relative Dominance

Dispersion pattern: The dispersion pattern exhibited by each species can be determined by calculating the Whitford index:

$$\text{Dispersion pattern} = \frac{\text{Abundance}}{\text{Frequency}}$$

Based on the index value, species were grouped into the following categories-

Regular: A/F ratio < 0.025

Random: A/F ratio = 0.025 – 0.050

Clumped: A/F ratio > 0.050

Biodiversity indices

The following diversity indices were used to assess the diversity of trees in the study site

Diversity index:

Shannon-Weiner Diversity Index (H') (Shannon & Wiener, 1963):

$$H' = - \sum \left(\frac{n_i}{N} \right) \ln \left(\frac{n_i}{N} \right)$$

Where,

n_i = No. of individuals in the i^{th} species

N = Total no. of individuals

Evenness index:

Evenness was calculated using Pielou's evenness index (E) (Pielou, 1975):

$$E = \frac{H'}{\ln S}$$

Where,

H' = Shannon index value

S = Total number of species

Dominance Index:

Simpson Index of Dominance (D) (Simpson, 1949):

$$D = \sum \frac{(n_i(n_i - 1))}{(N(N - 1))}$$

Where,

n_i = No. of individuals in the i^{th} species

N = Total number of individuals

Sorensen similarity index:

Similarity between two communities were computed using Sorensen similarity index (Sørensen, 1948)

$$\text{Similarity Index (\%)} = \frac{2C}{(A + B)} \times 100$$

Where,

A = No. of species in community A

B = No. of species in community B

C = No. of species common to both communities

Statistical analyses

Linear regression analysis was employed to explore the associations between the forest attributes (Jaiswal & Jayakumar, 2024). Logistic regression analysis was used to model the probability of tree and species absence. In order to select predictor variables, stepwise logistic model was performed and only those variables that were statistically significant in the Wald z-test were included in the logistic models. Models were compared based on their Akaike Information Criterion (AIC) and the model with the lowest AIC was selected. The influence of each predictor variable was compared using their odd ratio (OR) and confidence interval (CI). To predict the probability of tree absence in the buffer zone, a multiple logistic

regression with three predictor variables, NTFP use, Red-listed, species density, and DBH was performed. For each tree in the core, it was recorded as absent in the buffer zone if there was no similar tree belonging to the same species and having the same DBH class, NTFP use, and Red-list status. The probability of species absence was modeled using the transformed density especially the inversed density (1/density) and the fourth root of the inverse because all the other predictor variables were not significant in the Wald z-test with only density showing a borderline significance. The best fit model was selected using their AICs. All statistical analyses were carried out using R (version 4.3.0; R Core Team, 2022) and MS Excel.

3.2.5. Assessment of human-wildlife conflict

Data collection

To assess the nature and extent of human-wildlife conflicts and identify factors driving these conflicts, and to assess people's perception on wildlife conservation, four fringe villages located in the buffer zone of Dampa Tiger Reserve were selected namely Damparengpui, Tuipuibari, West Phaileng, and Phuldungsei. The sample size was calculated using the Cochran formula -

$$n = \frac{z^2 \times \frac{p(1-p)}{e^2}}{1 + \frac{(z^2 \times p(1-p))}{e^2 N}}$$

Where,

n = sample size

z = selected critical value of desired confidence level, in this case 95% confidence level

e = margin of error-5%

p = the estimated proportion of an attribute present in the population.

830 households from Damparengpui, Tuipuibari, West Phaileng, and Phuldungsei villages were sampled; each household was taken as one unit of analysis (Photo plate 4). One consenting adult from each household was interviewed in the local language using a semi-structured questionnaire. Perception study was conducted using a five-point Likert scale where items ranged from strongly disagree to strongly agree (Kidane et al., 2024). Data on basic socio-economy and demography, incidents of crop raiding, domestic animal depredation by wild animals, and human casualties by

wildlife, mitigation measures, and perceptions were collected through the questionnaire survey (Appendix-A).

Variables selection

Factors associated with wildlife- induced crop damage, livestock depredation, human casualties, and compensation access in the DTR were identified using model selection. Variables that were hypothesized to influence HWC were selected. To model crop loss, variables like distance of the farm from Dampa Tiger Reserve, proximity to the water source, the type of agriculture practiced, major crops cultivated, and presence of any guarding or protective measures were considered. Variables such as village, livestock management practices, and reasons for keeping domestic animals were the selected for modeling livestock depredation. In addition, village, problem type such as crop loss, livestock depredation, property damage and human casualty, and the reported monetary loss due to wildlife were the variables included in modeling compensation claim. To assess collinearity among variables, we computed Pearson's correlation coefficient for non-categorical variables. For categorical variables, the Chi-square (X^2), followed by Cramer's V test was adopted to measure the strength of their association. Kruskal- Wallis rank sum test and Point-Biserial test were conducted to examine the relationship between categorical and non-categorical variables. Variables with high correlation ($r > 0.5$, Cramer's $V > 0.5$) were considered redundant and hence, resulted in the elimination of one variable from strongly correlated pairs (Cohen, 1988; Milda et al., 2023; Sharma et al., 2020) (Appendix-B).

Data analysis

A priori set of models were developed representing the hypotheses about factors associated with wildlife induced loss and access to compensation (Appendix C-E). Assessment of model fit was based on the corrected Akaike's Information Criterion (AICc). Top models were selected using the relative differences in AIC (Δ) and weights of the model (w_i) that could best describe the pattern of loss and identify variables most significantly associated with loss and compensation access (Burnham & Anderson, 2002). The AICc weights were used as an indicator of the relative appropriateness of a given model in comparison to the entire model set and to rank models. The top models ($\Delta AICc < 2$), providing the most optimal offset between

model fit and parsimony were identified.

Socio-economic factors influencing perceptions of the local community towards wildlife conservation and DTR were examined using multiple linear regression models. Assumptions of multiple linear regressions such as normality, linearity, homoscedasticity, and autocorrelation were tested (Kidane et al., 2024).



Photo plate 4: Photographs of questionnaire survey

4.1. Landuse/land cover change analysis

The dominant land use/land cover type in 2011 was forest, which covered an area of 752.05 sq. km and accounted for 90.64 % of the total area. The second largest land use category was the combined class of jhumland and barren land, encompassing 74 sq. km and representing 9.03 % of the total area. Built up and water bodies were much smaller, covering 2.56 sq. km (0.31%) and 0.22 sq. km (0.03%) of the total land, respectively (Figure 4.1.1).

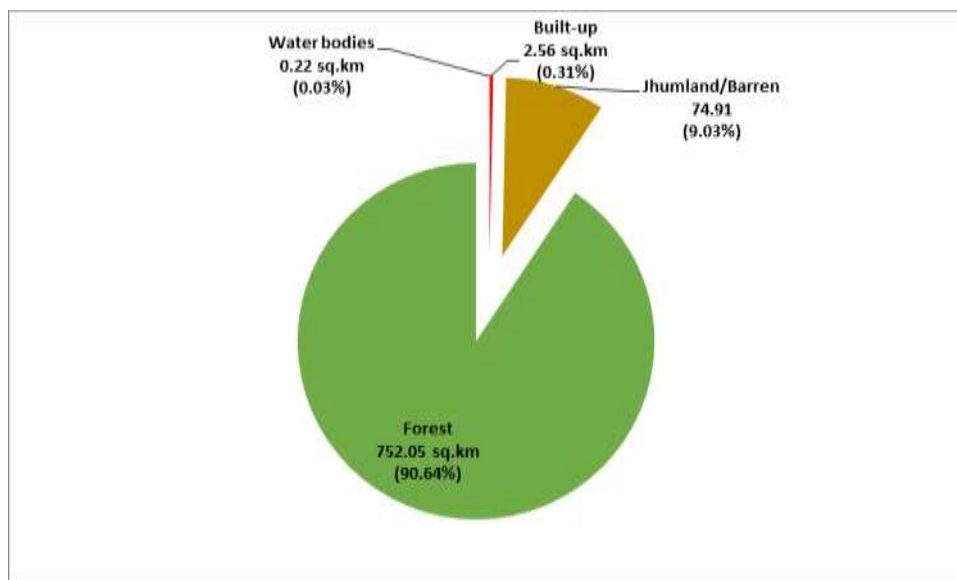


Figure 4.1.1 Pie chart showing the distribution of LULC in 2011

Forest remained the dominant land use/land cover type in 2021, encompassing an area of 737 sq. km and accounting for 88.93 % of the total land area (Figure 4.1.2). The combined category of jhumland and barren land covered an area of 82.32 sq. km, representing 9.92 % of the total land cover. Built-up land covered 8.84 sq. km, accounting for 1.07 % of the total area. Water bodies remained the least dominant land use category, with an area of 0.73 sq. km, constituting just 0.09% of the total land area.

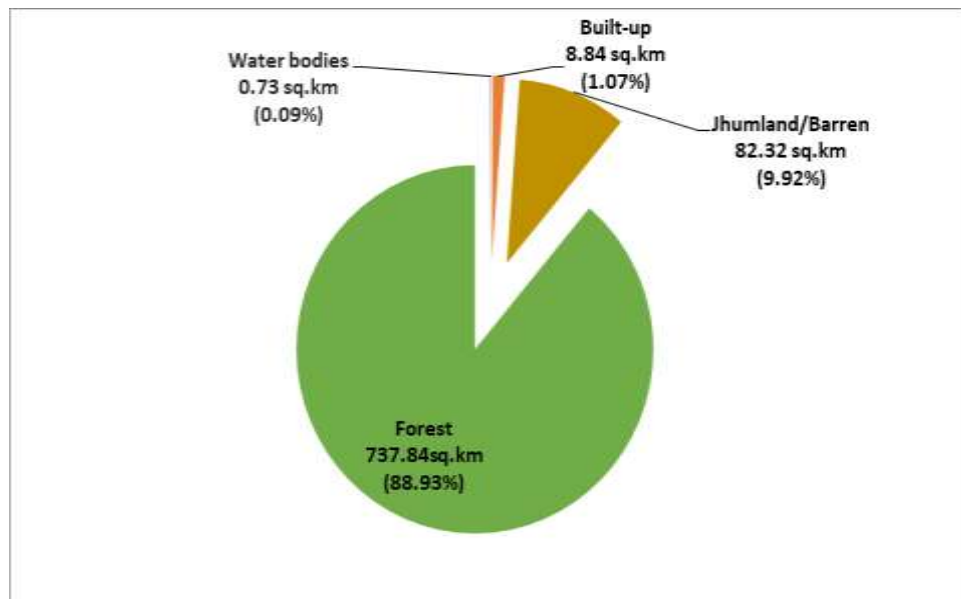


Figure 4.1.2 Pie chart showing the distribution of LULC in 2021

The analysis of land use land cover (LULC) change between 2011 and 2021 in DTR revealed notable shifts in land cover distribution. The spatial distribution of change between the two years showed that most of the land use changes are concentrated within the buffer zone of the reserve, where anthropogenic activity is highest. Forest continued to be the dominant land cover in both 2011 and 2021, however a decline in forest cover was observed, decreasing from 752 sq. km in 2011 to 737 sq. km in 2021. In contrast, the rest of the land use categories such as jhumland/barren, built-up areas, and water bodies exhibited an increasing trend over the decade. Satellite image and land use/land cover map of DTR for 2011 are presented in Figure 4.1.3 and Figure 4.1.4. Similarly, satellite image and land use/land cover map of DTR for 2021 are presented in Figure 4.1.5 and Figure 4.1.6.

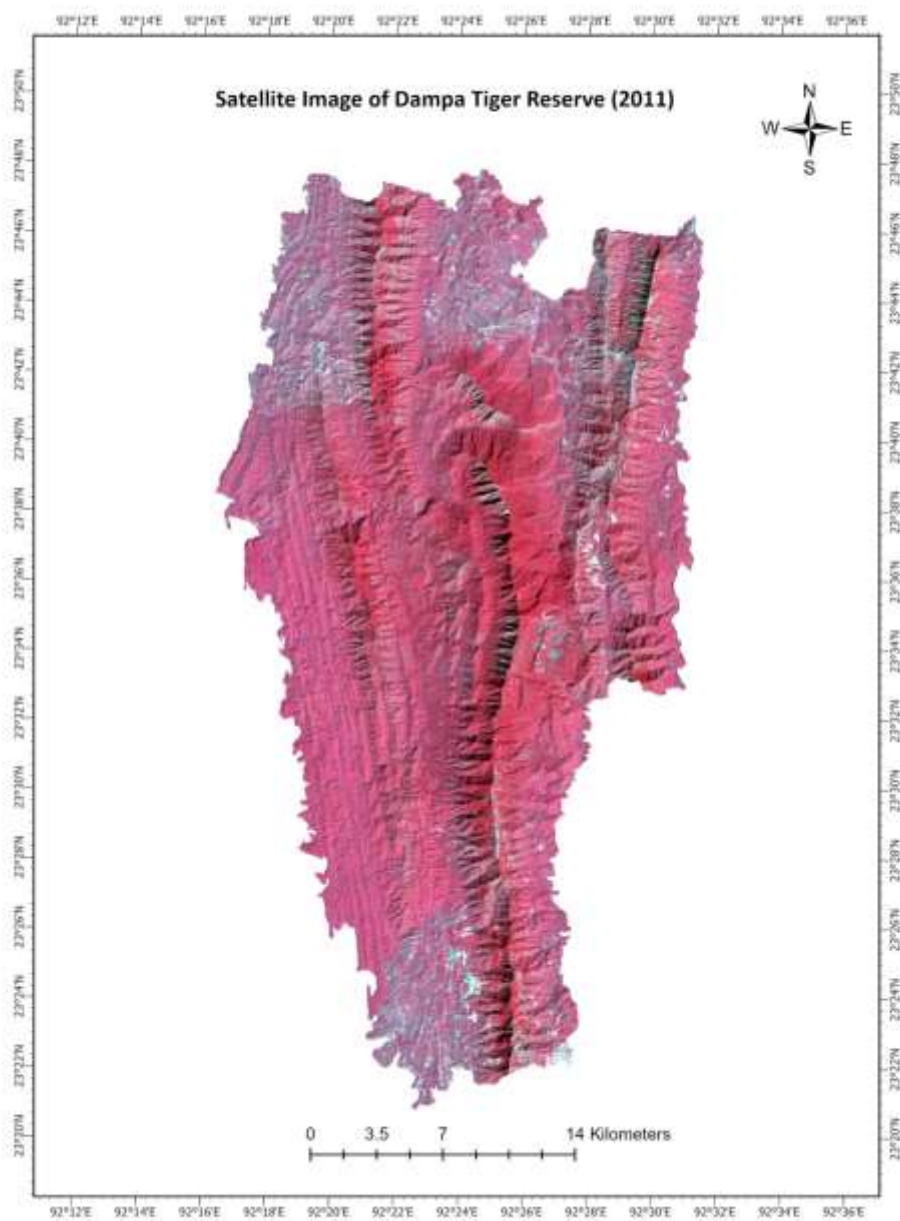


Figure 4.1.3 Satellite image of DTR (2011)

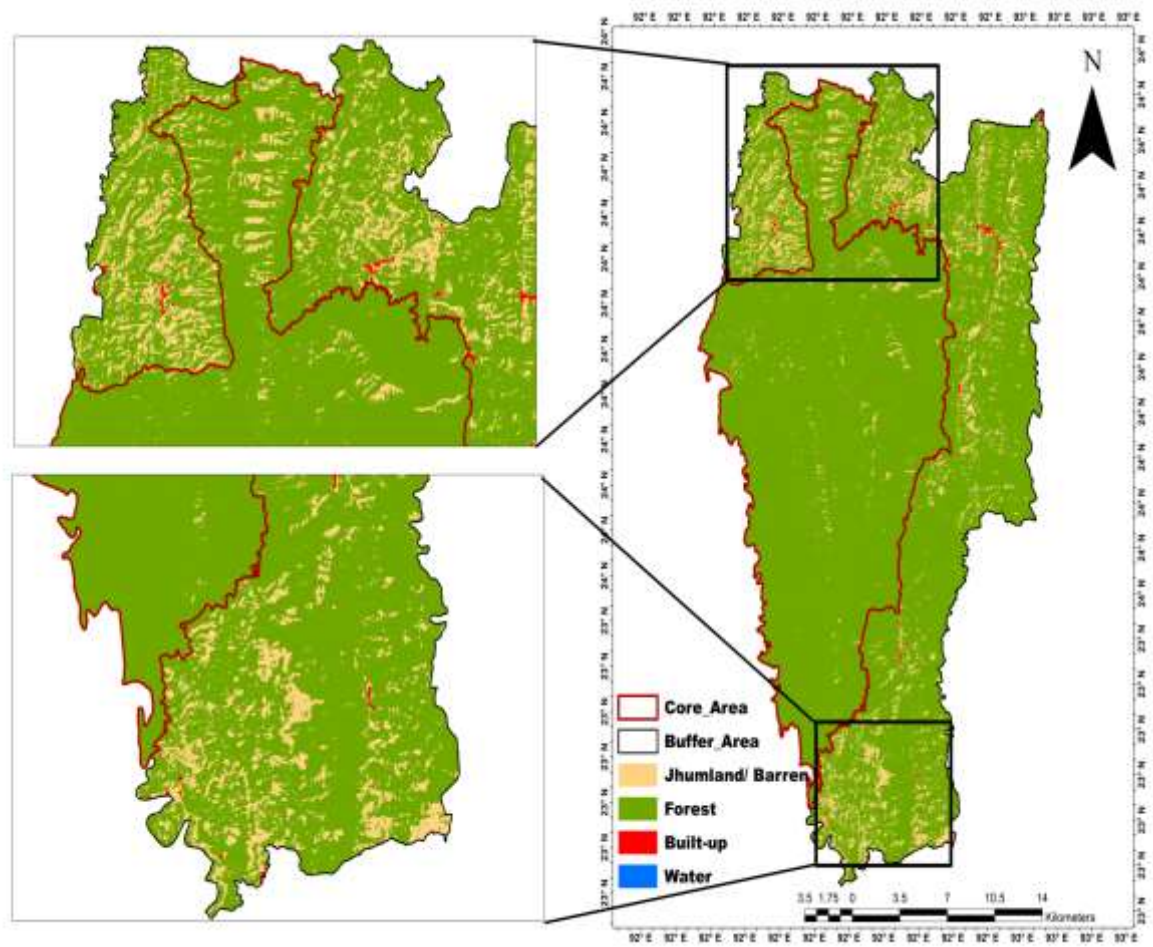


Figure 4.1.4 LULC map of 2011

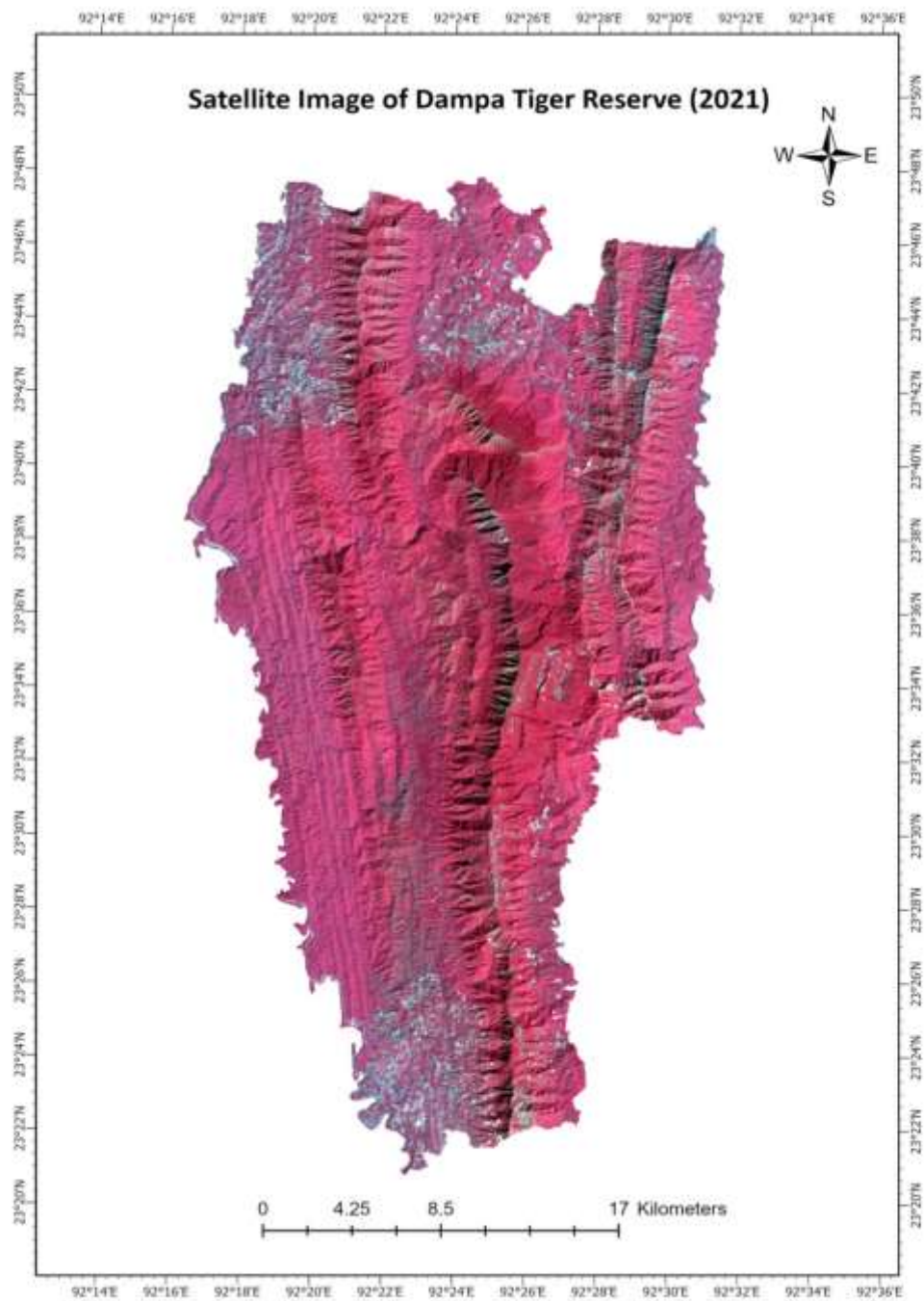


Figure 4.1.5 Satellite image of DTR (2021)

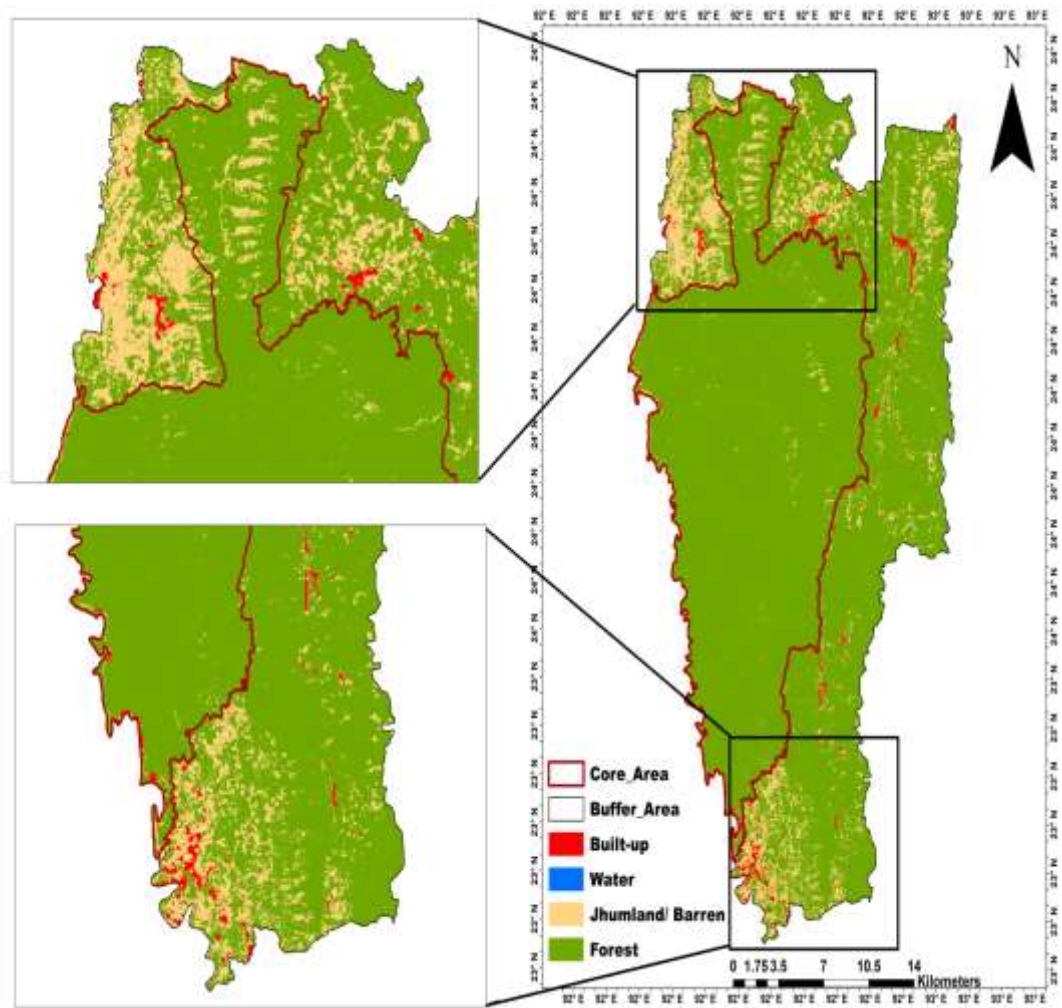


Figure 4.1.6 LULC map of 2021

The model's performance was evaluated using a split-sample validation approach, where 30% of reference samples were reserved for testing, generating confusion matrices (PA: Producer's Accuracy, UA: User's Accuracy) to derive Overall Accuracy (OC) and Kappa coefficients (KC) for both study periods (Table 4.1.1). The 2011 classification achieved an Overall Accuracy of 83.7% (Kappa = 0.79), while the 2021 classification yielded an Overall Accuracy of 82.5% (Kappa = 0.90). The slight reduction in 2021 accuracy is attributed to minor spectral overlap in transitional forest regeneration zones.

Table 4.1.1 Accuracy assessment metrics for random forest classification of jhumland/barren land and forest classes in 2011 and 2021

Year	LULC Class	Producer's Accuracy %	User's Accuracy %	Overall Accuracy %	Kappa Coefficient
2011	Jhumland/Barren	84.5	82.1	83.7	0.81
	Forest	82.9	84.3		
2021	Jhumland/Barren	81.2	83.8	82.5	0.79
	Forest	83.7	80.5		

4.2. Microclimate

4.2.1. Air temperature as affected by land use systems

The highest mean air temperature was recorded from the current jhum cultivation site, followed by monoculture plantation of areca nut and teak. The secondary forest and oil palm plantation exhibited intermediate value while, the lowest value was recorded in the primary forest (Figure 4.2.1).

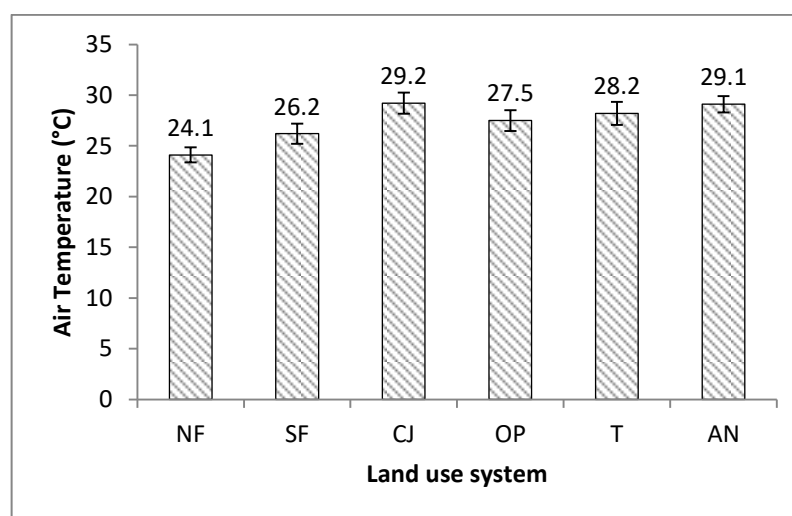


Figure 4.2.1 Mean value of air temperature ($\pm$ SE) under different land use systems

The Kruskal-Wallis rank sum test revealed significant air temperature variation across land use systems ($p = 0.00156$, $df = 5$) (Figure 4.2.2). Additionally, post hoc Dunn's test showed significant differences between natural forest and current jhum as well as areca nut plantation ($p < 0.05$) (Appendix F).

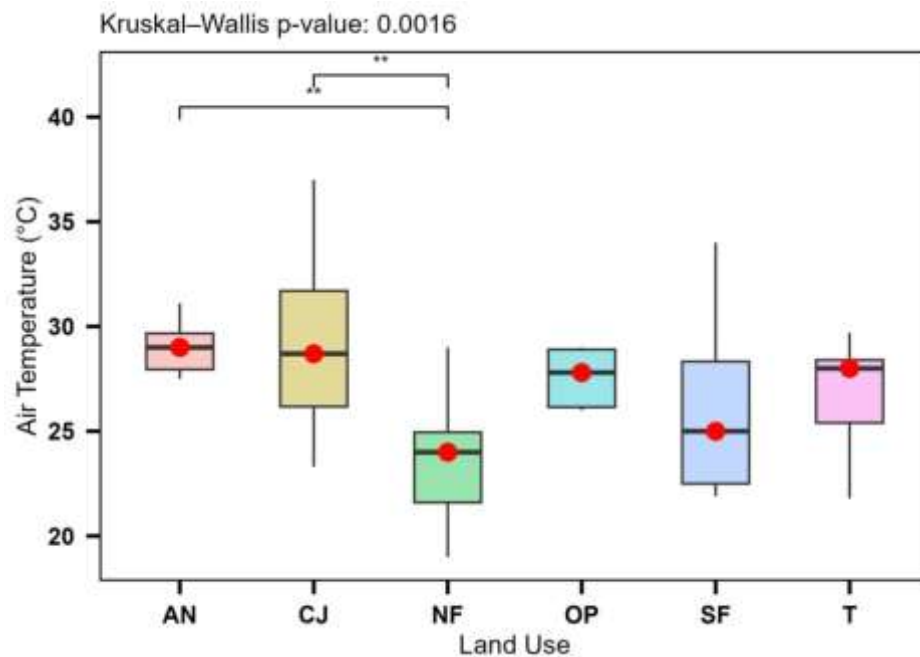


Figure 4.2.2 Box plot showing the distribution of air temperature (°C) across different land use types. The horizontal line in each box represents the median, the red dot indicates the mean, and whiskers denote the range excluding outliers. Significant pairwise differences ($p < 0.05$) are indicated above the boxes.

4.2.2. Air temperature as affected by seasons within each land use

The recorded mean air temperature showed significant seasonal variation within each land use system (Table 4.2.1 and Appendix G & H). Under each land use system, the maximum value was recorded during the pre-monsoon season, which was followed by monsoon and post-monsoon seasons. This general pattern was consistent for both the forest sites and the more intensively used landscapes, although the degree of change was not uniform. A notably steep decline in temperature from pre-monsoon to post-monsoon was observed in the current jhum, teak, and oil palm plantations, and secondary forest. In contrast, the decline in temperature was comparatively moderate in the natural forest and areca nut plantations.

Table 4.2.1 Seasonal means, medians, standard error (SE) for air temperature in each land use. Statistical comparisons used Welch ANOVA (F statistic) or Kruskal–Wallis (H statistic), test statistic, and p-value shown for each land use.

Land use	Season	Mean	Median	SE	Test Statistics	p-value
Natural Forest	Pre-Monsoon	26.9	26.9 ^a	1.25	11.76	.002
	Monsoon	24.5	24.6 ^a	0.18		
	Post Monsoon	20.8	21.2 ^b	0.43		
Secondary Forest	Pre-Monsoon	31.2	31.4 ^a	1.24	15.83	<.001
	Monsoon	25	25 ^{ab}	0		
	Post Monsoon	22.2	22.2 ^b	0.11		
Current Jhum	Pre-Monsoon	34.4 ^a	35.2	1.2	31.73	<.001
	Monsoon	28.5 ^b	28.7	0.16		
	Post Monsoon	24.8 ^c	24.8	0.54		
Oil Palm	Pre-Monsoon	30.7 ^a	30.8	1.81	7.29	.02
	Monsoon	28.5 ^a	28.6	0.18		
	Post Monsoon	23.4 ^b	23.6	1.34		
Teak	Pre-Monsoon	32.9	33.4 ^a	2.03	13.22	.001
	Monsoon	28	28 ^{ab}	0.02		
	Post Monsoon	23.6	23.2 ^b	0.72		
Areca Nut	Pre-Monsoon	32.2	33 ^a	1.34	8.03	.01
	Monsoon	28.8	29 ^{ab}	0.13		
	Post Monsoon	26.2	25.8 ^b	1.1		

Different letters indicate statistically significant differences between seasons within each land use.

4.2.3 Relative humidity as affected by land use systems

The average relative humidity under the natural forest was significantly higher than the other land use systems. The secondary forest and the areca nut and teak plantation had a relatively consistent mean humidity value, while the lowest humidity was recorded from the jhum site (Figure 4.2.3).

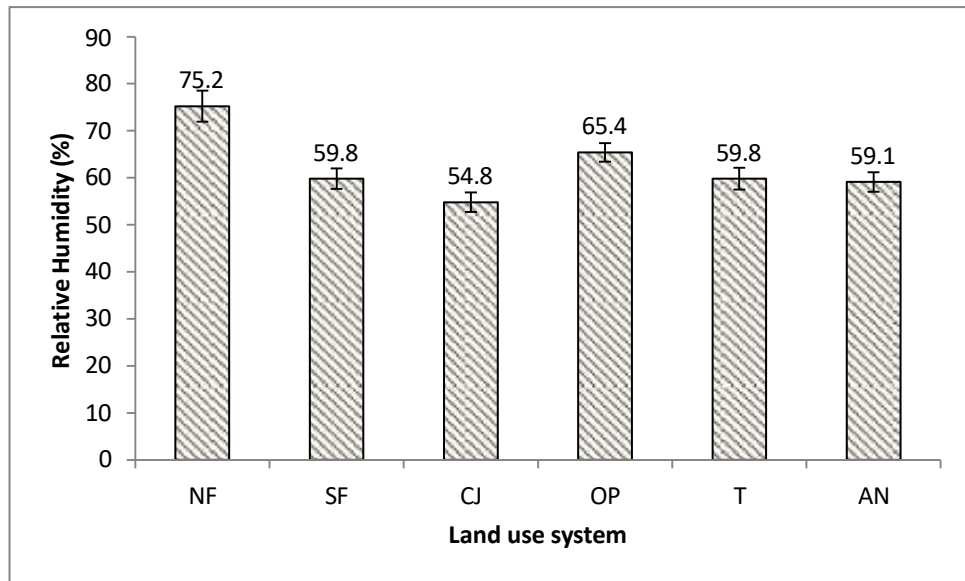


Figure 4.2.3 Mean value of relative humidity ($\pm$ SE) under different land use systems

The Kruskal-Wallis rank sum test revealed significant relative humidity variation across land use systems ($p < 0.001$, $df = 5$) (Figure 4.2.4). Post hoc Dunn's test showed significant differences between natural forest and current jhum as well as areca nut plantation ($p < 0.05$) (Appendix I).

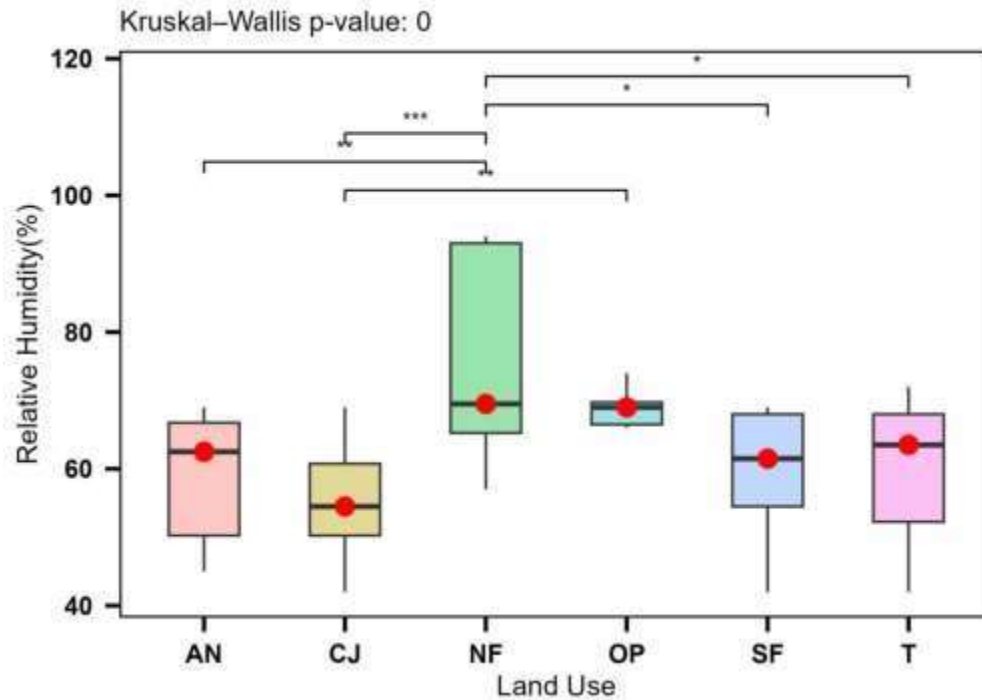


Figure 4.2.4 Box plot showing the distribution of relative humidity (%) across different land use types. The horizontal line in each box represents the median, the red dot indicates the mean, and whiskers denote the range excluding outliers. Significant pairwise differences ($p < 0.05$) are indicated above the boxes.

4.2.4 Relative humidity as affected by seasons within each land use

Across the different land-use systems, clear seasonal patterns in relative humidity was observed, with values peaked during the monsoon period and dropped again subsequently (Table 4.2.2 and Appendix J & K). Although this general trend was consistent across all sites, the degree of change differed depending on the land use. Natural and secondary forests showed a pronounced increase from the pre-monsoon to monsoon season, while plantations such as oil palm, teak, and areca nut displayed more moderate seasonal shifts. Current jhum plots, on the other hand, exhibited the strongest contrasts among seasons.

Table 4.2.2 Seasonal means, medians, standard error (SE) for relative humidity in each land use. Statistical comparisons used Welch ANOVA (F statistic), one way ANOVA (F statistics) or Kruskal–Wallis (H statistic), test statistic and p-value shown for each land use.

Land_use	Season	Mean	Median	SE	Test Statistics	p-value
Natural Forest	Pre-Monsoon	62.2	64 ^a	1.66	15.38	<.001
	Monsoon	93.7	94 ^b	0.21		
Secondary Forest	Post-Monsoon	69.8	69.5 ^{ab}	0.60	12.61	.001
	Pre-Monsoon	51.3	49 ^a	3.82		
	Monsoon	68.7	69 ^b	0.21	33.03	<.001
	Post-Monsoon	59.5	61 ^{ab}	1.69		
Current Jhum	Pre-Monsoon	45.5 ^a	42	2.39		
	Monsoon	64.5 ^b	64	1.57		
	Post-Monsoon	54.3 ^c	54	0.21		
Oil Palm	Pre-Monsoon	56.7	55 ^a	3.98	12.94	.001
	Monsoon	71	70 ^b	0.82		
	Post-Monsoon	68.7	69 ^{ab}	0.21		
Teak	Pre-Monsoon	47.7	46 ^a	2.06	15.25	<.001
	Monsoon	69.2	68.5 ^b	0.65		
	Post-Monsoon	62.7	63.5 ^{ab}	1.23		
Areca Nut	Pre-Monsoon	48	48 ^a	1.06	13.23	.001
	Monsoon	66.7	67 ^b	0.21		
	Post-Monsoon	62.7	62.5 ^{ab}	1.69		

Different letters indicate statistically significant differences between seasons within each land use at $p < 0.5$.

4.3. Soil physicochemical assessment

The collected samples were analyzed to determine the seasonal soil properties and the quality index under the selected land use systems.

4.3.1 Comparison of mean values of soil parameters between land use systems

Overall soil depth (0 – 20 cm)

The average bulk density value ranged from 1.2 g/cm³ to 1.4 g/cm³. It is maximum in soil under the teak plantation and minimum under the natural forest. Soil under the natural forest had the maximum moisture content, followed by areca nut plantation, while soil under the teak plantation had the minimum recorded moisture content. Meanwhile, the oil palm plantation site, jhum cultivation, and the secondary forest exhibited soil moisture content ranging from 19.3% to 19.8%. The water holding capacity of soil also followed similar trend as the moisture content with maximum WHC recorded from the natural forest and minimum from the teak plantation site. The one way ANOVA followed by Tukey's post hoc test showed significant differences in soil temperature and water holding capacity across the different land use types, whereas the variation in soil bulk density and moisture content were not statistically significant (Table 4.3.1 and Table 4.3.3). Detailed Tukey's post hoc results are provided in Appendix L and M.

Table 4.3.1 Mean values of soil physical properties as affected by land use

LULC	Temperature (°C)	BD (g/cm ³)	MC (%)	WHC (%)	Texture class
NF	22.3±2.4 ^c	1.2±0.3 ^a	20.6±6.8 ^a	36.9±5.6 ^a	Sand
SF	25.6±3.7 ^{ab}	1.3±0.3 ^a	19.8±6.4 ^a	33.6±4.4 ^{bc}	Sand
CJ	27.6±6.2 ^a	1.3±0.3 ^a	19.6±7.3 ^a	35.5±2.8 ^{aab}	Sand
OP	24.9±3.4 ^{bc}	1.3±0.3 ^a	19.3±7.8 ^a	32.2±3.1 ^{cd}	Sand
T	25.3±3.3 ^{ab}	1.4±0.3 ^a	17.0±9.1 ^a	30.3±4.5 ^d	Sand
AN	25.7±3.3 ^{ab}	1.3±0.3 ^a	20.3±8.3 ^a	34.5±3.4 ^{abc}	Sand

Different upper case letters are significantly different at p<0.001 between land use

The soils under the studied land use systems were determined to be acidic in reaction with the mean pH values recorded as low as 4.9 under the natural forest and as high as 5.3 under the teak plantation site. The average value of soil organic carbon was the highest under the natural forest (1.6%) and the lowest under the teak plantation site (0.9%). Similar pattern was observed for soil organic matter as well, with the maximum SOM (2.8%) under natural forest and the minimum under the teak plantation (1.5%). The soil under the jhum cultivation had the highest available nitrogen content (242.8 kg/ha), followed by the natural forest (239.4 kg/ha) and the least available nitrogen content was observed under the teak plantation site (210.1 kg/ha). The natural forest exhibited the highest mean value of soil available phosphorus (12.5 kg/ha) while the lowest value (6.5 kg/ha) was observed under the areca nut plantation site. The soil available potassium was observed to be the highest in the jhum cultivation site (387.7 kg/ha) and lowest in the teak plantation site (382.4kg/ha). Soil chemical parameters varied significantly among the different land use systems, except for pH, which showed no significant variation (Table 4.3.2 and Table 4.3.3). Detailed Tukey's post hoc results are provided in Appendix N-R.

Table 4.3.2 Mean values of soil chemical properties as affected by land use

LULC	pH	SOC (%)	SOM (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
NF	4.9±0.5 ^a	1.62±0.5 ^a	2.8±0.8 ^a	239.4±13.4 ^a	12.5±4.0 ^a	382.4±13.6 ^a
SF	5.0±0.4 ^a	1.00±0.3 ^c	1.7±0.3 ^c	224.1±19.8 ^b	7.7±3.3 ^c	360.5±14.3 ^b
CJ	5.0±0.5 ^a	1.29±0.4 ^b	2.2±0.7 ^b	242.8±14.1 ^a	10.4±2.8 ^{ab}	387.7±27.8 ^a
OP	5.1±0.6 ^a	1.05±0.4 ^{bc}	1.8±0.7 ^{bc}	226.2±15.6 ^b	8.3±3.9 ^{bc}	339.3±20.8 ^{cd}
T	5.3±0.4 ^a	0.88±0.5 ^c	1.5±0.8 ^c	210.4±14.1 ^c	7.3±2.8 ^c	326.8±17.1 ^d
AN	5.0±0.4 ^a	1.01±0.4 ^b ^c	1.7±0.7 ^c	226.1±12.8 ^b	6.5±2.2 ^c	351.9±18.4 ^{bc}

Different upper case letters are significantly different at $p < 0.001$ between land use

Table 4.3.3 Summary of one way ANOVA showing variations in soil parameter (overall depth) across the different land use systems

Source of Variation	df	F	Sig
Soil temperature	5	6.93	<.001***
BD	5	1.32	0.26
MC	5	1.007	0.415
WHC	5	11.79	<.001***
pH	5	0.46	0.06
SOC	5	15.34	<.001***
SOM	5	15.34	<.001***
AN	5	21.06	<.001***
AP	5	17	<.001***
AK	5	54.31	<.001***

*** p < 0.001

Soil depth 0 – 10 cm

At the upper soil depth (0 – 10 cm), the mean soil temperature was maximum under the jhum cultivation site (28.3°C), followed by the areca nut plantation (25.9°C), while the minimum soil temperature was recorded under the natural forest (22.3°C). Soil bulk density across the selected land use systems were comparatively stable, with values ranging from 1.1 – 1.3 g/cm³. The mean moisture content was the highest under the natural forest (21.5 %), and was the lowest under the teak plantation site (16.7 %). The water holding capacity of soil followed the same trend as the soil moisture content with the highest mean value under natural forest (39.4 %) and the lowest value reported from the teak planation site (30.7 %). Soil temperature and water holding capacity varied significantly across the land use types (Table 4.3.4

and Table 4.3.6). Detailed Tukey's post hoc results are presented in Appendix-S and T.

Table 4.3.4 Mean Values ($\pm$ SD) of soil physical properties (0 – 10 cm) as affected by land use

LULC	Temperature (°C)	BD (g/cm³)	MC (%)	WHC (%)
NF	22.3 $\pm$ 2.5 ^b	1.1 $\pm$ 0.3 ^a	21.5 $\pm$ 8.1 ^a	39.4 $\pm$ 6.1 ^a
SF	25.6 $\pm$ 4.1 ^{ab}	1.3 $\pm$ 0.3 ^a	19.7 $\pm$ 6.7 ^a	33.8 $\pm$ 4.8 ^{bc}
CJ	28.3 $\pm$ 6.9 ^a	1.2 $\pm$ 0.4 ^a	20.6 $\pm$ 8.4 ^a	36.1 $\pm$ 2.1 ^{ab}
OP	25.2 $\pm$ 3.8 ^{ab}	1.3 $\pm$ 0.3 ^a	19.1 $\pm$ 10.2 ^a	32.5 $\pm$ 4.2 ^{bc}
T	25.5 $\pm$ 3.6 ^{ab}	1.3 $\pm$ 0.3 ^a	16.7 $\pm$ 10.3 ^a	30.7 $\pm$ 4.7 ^c
AN	25.9 $\pm$ 3.7 ^{ab}	1.2 $\pm$ 0.3 ^a	20.3 $\pm$ 9.7 ^a	34.8 $\pm$ 2.8 ^{bc}

Different upper case letters are significantly different at $p < 0.001$ between land use

The studied soil chemical properties at 0 – 10cm exhibited significant variation across the selected land use systems with the exception of soil pH. The mean pH value ranged from 5 to 5.1 with the lowest value observed under natural forest and areca nut plantation, and the highest value observed under the oil palm and teak plantation. Soil organic carbon and soil organic matter followed similar trend, being maximum under the natural forest and minimum under the teak plantation site. The soil available nitrogen was significantly higher in the jhum cultivation site (249 kg/ha) than the other land use systems, and it is lowest in the teak plantation site (215.4 kg/ha). Similarly, the soil available potassium content was the highest in the jhum site (410 kg/ha) and lowest in the teak plantation site (329.5 kg/ha). Additionally, the land use system that reported the maximum soil available phosphorus was natural forest (14.6kg/ha), while the areca nut plantation site had the

lowest available P content (7.2 kg/ha) (Table 4.3.5 and Table 4.3.6). Detailed Tukey's post hoc results are presented in Appendix-U – Y.

Table 4.3.5 Mean Values ($\pm$ SD) of soil chemical properties (0 – 10cm) as affected by land use

LULC	pH	SOC (%)	SOM (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
NF	5.0 $\pm$ 0.6 ^a	1.9 $\pm$ 0.5 ^a	3.21 $\pm$ 0.8 ^a	246.4 $\pm$ 8.6 ^{ab}	14.6 $\pm$ 3.8 ^a	390.5 $\pm$ 7.2 ^b
SF	5.1 $\pm$ 0.4 ^a	1.1 $\pm$ 0.2 ^c	1.9 $\pm$ 0.4 ^c	231.6 $\pm$ 17.8 ^c	8.5 $\pm$ 2.9 ^c	368.3 $\pm$ 12.2 ^c
CJ	5.1 $\pm$ 0.6 ^a	1.5 $\pm$ 0.4 ^{ab}	2.7 $\pm$ 0.7 ^{ab}	249.0 $\pm$ 14.4 ^a	12.0 $\pm$ 2.6 ^{ab}	410.0 $\pm$ 7.4 ^a
OP	5.3 $\pm$ 0.6 ^a	1.2 $\pm$ 0.4 ^{bc}	2.1 $\pm$ 0.7 ^{bc}	235.2 $\pm$ 4.4 ^{bc}	9.59 $\pm$ 4.0 ^{bc}	346.9 $\pm$ 21.9 ^d
T	5.3 $\pm$ 0.4 ^a	1.0 $\pm$ 0.5 ^c	1.8 $\pm$ 0.8 ^c	215.4 $\pm$ 11.7 ^d	8.1 $\pm$ 2.5 ^c	329.5 $\pm$ 14.1 ^e
AN	5.0 $\pm$ 0.3 ^a	1.2 $\pm$ 0.4 ^{bc}	2.0 $\pm$ 0.7 ^{bc}	230.6 $\pm$ 10.1 ^c	7.2 $\pm$ 10 ^c	358.9 $\pm$ 13.5 ^{cd}

Different upper case letters are significantly different at $p < 0.001$ between land use

Table 4.3.6 Summary of one way ANOVA showing variations in soil parameter (0 – 10cm) across the different land use systems

Source of Variation	df	F	Sig
BD	5	1.539	0.184
MC	5	0.602	0.699
WHC	5	9.164	<.001***
pH	5	1.087	0.372
SOC	5	10.89	<.001***
SOM	5	10.89	<.001***
AN	5	18.69	<.001***
AP	5	15.24	<.001***
AK	5	82.77	<.001***

*** p < 0.001; ** p < 0.01

Soil depth 10 – 20 cm

The soil physical parameters at 10 – 20 cm varied significantly across the land use systems, except for bulk density and moisture content. The maximum soil temperature was observed under the jhum cultivation, while the minimum value was from the natural forest site. The mean soil bulk density varied between 1.3 and 1.4 g/cm³, and the maximum BD value was under the teak plantation site. Soil under the areca nut plantation exhibited the highest moisture content (20.3%), while soil under teak plantation site recorded the least moisture content (17.2%). Soil under natural forest and jhum cultivation sites had the highest capacity to hold water, while those under teak plantation site had the least capacity to hold water (Table 4.3.7 and Table 4.3.9). Detailed Tukey's post hoc results are presented in Appendix-Z and AA.

Table 4.3.7 Mean Values ($\pm$ SD) of soil physical properties (10 – 20 cm) as affected by land use

LULC	Temperature (°C)	BD (g/cm³)	MC (%)	WHC (%)
NF	22.3 $\pm$ 2.5 ^b	1.3 $\pm$ 0.3 ^a	19.6 $\pm$ 5.5 ^a	34.9 $\pm$ 4.2 ^a
SF	25.7 $\pm$ 3.4 ^{ab}	1.3 $\pm$ 0.3 ^a	19.9 $\pm$ 6.4 ^a	33.4 $\pm$ 4.2 ^{ab}
CJ	26.9 $\pm$ 5.6 ^a	1.3 $\pm$ 0.4 ^a	18.6 $\pm$ 6.1 ^a	34.9 $\pm$ 3.2 ^a
OP	24.5 $\pm$ 3.0 ^{ab}	1.3 $\pm$ 0.3 ^a	19.5 $\pm$ 4.6 ^a	32.0 $\pm$ 1.5 ^{ab}
T	25.2 $\pm$ 3.1 ^{ab}	1.4 $\pm$ 0.3 ^a	17.2 $\pm$ 8.1 ^a	29.9 $\pm$ 4.8 ^b
AN	25.5 $\pm$ 2.7 ^{ab}	1.3 $\pm$ 0.3 ^a	20.3 $\pm$ 7.1 ^a	34.2 $\pm$ 4.0 ^a

Different upper case letters are significantly different at $p < 0.001$ between land use

The soil chemical characteristics were revealed to vary significantly across the different land use types, except for the pH. The SOC and SOM followed a similar pattern with the highest content of these parameters reported under the natural forest (1.39% and 2.39%), and the lowest under the teak plantation site (0.73 % and 1.27%). The maximum soil available nitrogen was from the jhum cultivation site (236.6 kg/ha), and the minimum was from the teak plantation with a mean value of 205.3 kg/ha. The highest and lowest content of soil available phosphorus were reported under the natural forest and the areca nut plantation with mean values of 10.4 kg/ha and 5.89 kg/ha respectively. In addition, soil under the natural forest recorded the maximum soil available potassium content (374.4 kg/ha) and the minimum from the teak plantation site (324.1 kg/ha) (Table 4.3.8 and Table 4.3.9). Detailed Tukey's post hoc results are presented in Appendix AB – AF.

Table 4.3.8 Mean Values ($\pm$ SD) of soil chemical properties (10 – 20 cm) as affected by land use

LULC	pH	SOC (%)	SOM (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
NF	4.84 $\pm$ 0.4 ^a	1.39 $\pm$ 0.5 ^a	2.39 $\pm$ 0.5 ^a	232.4 $\pm$ 13.8 ^a	10.4 $\pm$ 3.3 ^a	374.4 $\pm$ 14.1 ^a
SF	4.95 $\pm$ 0.5 ^a	0.87 $\pm$ 0.2 ^b	1.50 $\pm$ 0.5 ^b	216.5 $\pm$ 19.1 ^{bc}	6.96 $\pm$ 3.6 ^{bc}	352.7 $\pm$ 11.9 ^{bc}
CJ	4.97 $\pm$ 0.6 ^a	1.02 $\pm$ 0.3 ^b	1.76 $\pm$ 0.5 ^b	236.6 $\pm$ 10.9 ^a	8.80 $\pm$ 2.1 ^{ab}	365.4 $\pm$ 22.0 ^{ab}
OP	4.86 $\pm$ 0.5 ^a	1.00 $\pm$ 0.3 ^b	1.55 $\pm$ 0.5 ^b	217.2 $\pm$ 17.5 ^{bc}	6.93 $\pm$ 3.4 ^{bc}	331.6 $\pm$ 17.1 ^{de}
T	5.22 $\pm$ 0.4 ^a	0.73 $\pm$ 0.5 ^b	1.27 $\pm$ 0.8 ^b	205.3 $\pm$ 16.4 ^c	6.58 $\pm$ 2.8 ^{bc}	324.1 $\pm$ 21.2 ^e
AN	4.92 $\pm$ 0.4 ^a	0.83 $\pm$ 0.4 ^b	1.45 $\pm$ 0.6 ^b	221.6 $\pm$ 13.8 ^{ab}	5.89 $\pm$ 2.4 ^c	344.7 $\pm$ 20.25 ^{cd}

Different upper case letters are significantly different at $p <$ between land use

Table 4.3.9 Summary of one way ANOVA showing variations in soil parameter (10 – 20 cm) across the different land use systems

Source of Variation	df	F	Sig
Soil temperature	5	3.423	0.0067 **
BD	5	0.456	0.808
MC	5	0.559	0.731
WHC	5	4.394	0.00115 **
pH	5	1.649	0.154
SOC	5	8.459	<.001 ***
SOM	5	8.459	<.001 ***
AN	5	9.728	<.001 ***
AP	5	5.702	<.001 ***
AK	5	20.42	<.001 ***

*** $p < 0.001$; ** $p < 0.01$

4.3.2. Soil Properties under each land use as affected by seasons and depth

Natural Forest

The natural forest soil recorded maximum temperature in the pre-monsoon season, followed by the monsoon and post-monsoon season. Soil bulk density was observed to be the highest during the pre-monsoon season, followed by the post-monsoon and monsoon season. Moisture content and water holding capacity of soil exhibited a clear seasonal trend, being highest during the monsoon followed by post-monsoon and the least during the pre-monsoon period. All soil chemical parameters followed a consistent seasonal trend- post-monsoon > pre-monsoon > monsoon (Table 4.3.10). The physicochemical parameters of soil under the natural forest varied significantly across seasons. Detailed one-way ANOVA and Tukey's post hoc results are presented in Appendix AG and AH.

Table 4.3.10 Mean values ($\pm$ SD) of soil parameters under Natural Forest as affected by seasons

Soil Parameters	Seasons		
	Pre-Monsoon	Monsoon	Post-Monsoon
Temperature ($^{\circ}$ C)	23.9 $\pm$ 1.08 ^a	23.7 $\pm$ 0.881 ^a	19.3 $\pm$ 1.72 ^b
BD (g/cm ³)	1.33 $\pm$ 0.236 ^b	0.94 $\pm$ 0.168 ^a	1.29 $\pm$ 0.299 ^a
MC (%)	14.0 $\pm$ 4.83 ^c	28.4 $\pm$ 2.71 ^a	19.3 $\pm$ 2.23 ^b
WHC (%)	32.1 $\pm$ 5.45 ^b	39.4 $\pm$ 4.73 ^a	39.3 $\pm$ 3.76 ^a
pH	5.01 $\pm$ 0.399 ^b	4.61 $\pm$ 0.215 ^a	5.18 $\pm$ 0.628 ^{ab}
SOC (%)	1.47 $\pm$ 0.375 ^b	1.45 $\pm$ 0.358 ^a	1.95 $\pm$ 0.476 ^b
SOM (%)	2.54 $\pm$ 0.647 ^b	2.50 $\pm$ 0.617 ^a	3.36 $\pm$ 0.820 ^b
AN (kg/ha)	236.33 $\pm$ 11.5 ^b	234.54 $\pm$ 16.2 ^a	247.65 $\pm$ 8.87 ^{ab}
AP (kg/ha)	12.3 $\pm$ 5.05 ^b	9.97 $\pm$ 1.56 ^a	15.2 $\pm$ 3.22 ^{ab}
AK (kg/ha)	373.09 $\pm$ 13.2 ^b	383.21 $\pm$ 10.9 ^a	390.93 $\pm$ 11.6 ^{ab}

Different upper case letters are significantly different at $p < 0.05$ between seasons

In the natural forest site, the Welch's two samples t-test indicated a significant difference in soil bulk density and water holding capacity between the two sampled depths at $p < 0.05$. The bulk density was higher in the 10 – 20 cm than the 0 – 10 cm depth, whereas the water holding capacity exhibited the opposite trend.

Soil temperature and moisture content did not differ significantly between the two soil depths at $p < 0.05$ (Figure 4.3.1)

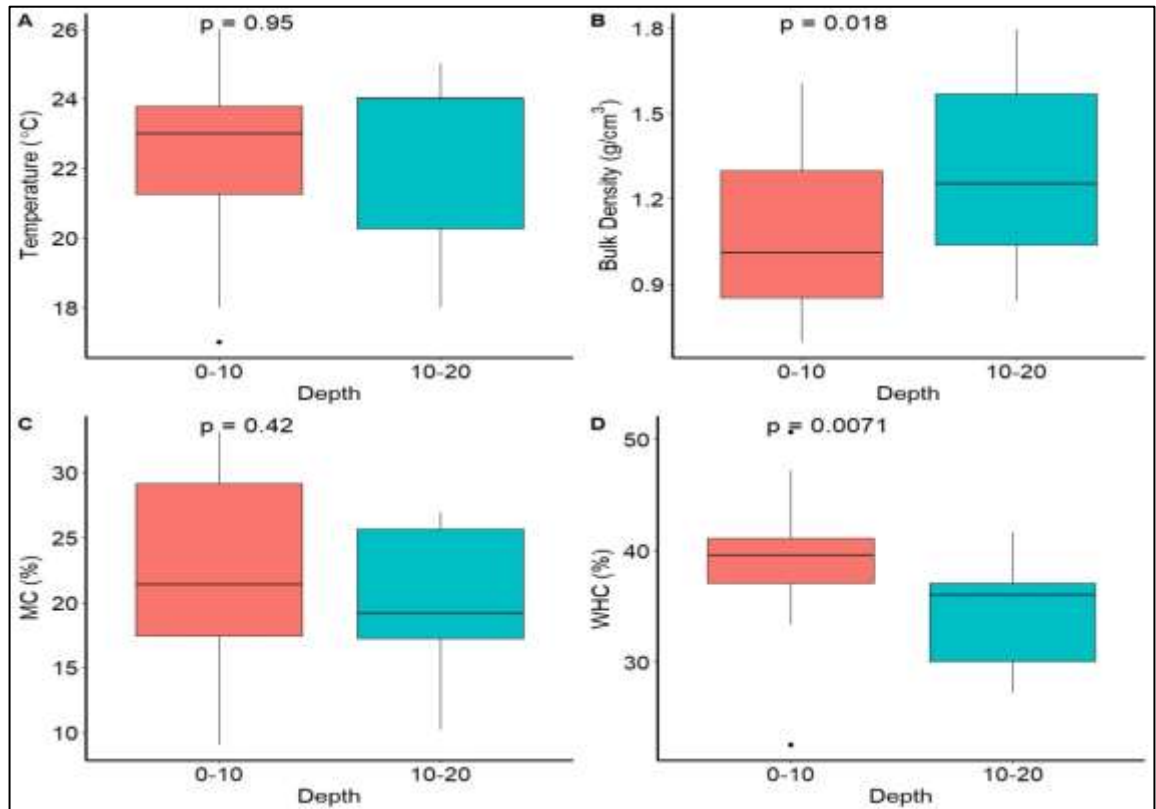


Figure 4.3.1 Box plot showing the distribution of soil (A) temperature (B) bulk density (C) moisture content (D) water holding capacity at different depths under the natural forest

pH was the only measured soil chemical parameter that did not show statistical significance with depth at $p < 0.05$. The mean SOC, SOM, available nitrogen, phosphorus and potassium were significantly higher in the upper soil depth (Figure 4.3.2).

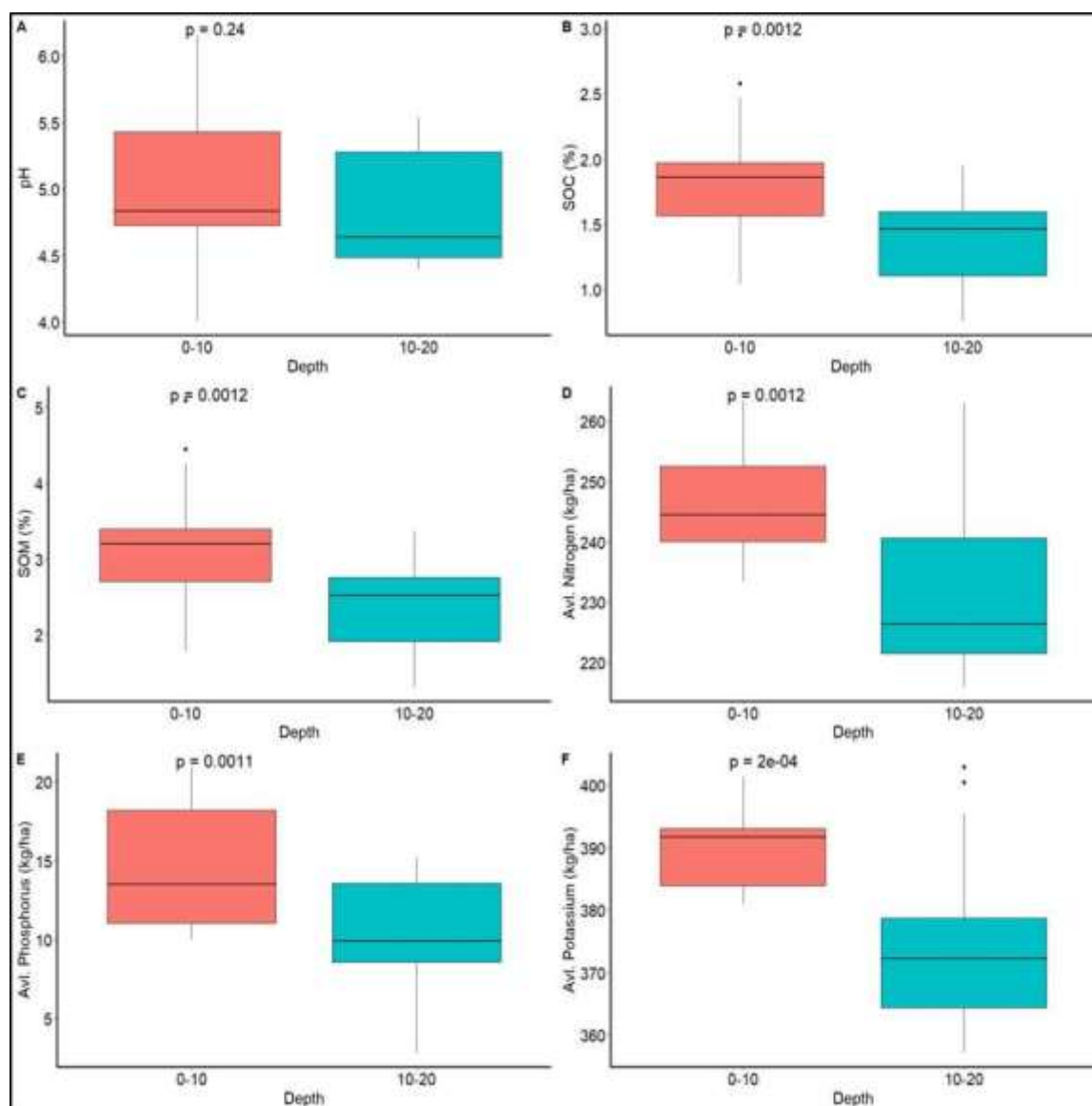


Figure 4.3.2 Box plot showing the distribution of soil (A) pH (B) SOC (C) SOM (D) Available nitrogen (E) Available Phosphorus (F) Available Potassium at different depths under the natural forest

Secondary Forest

Soil under the secondary forest exhibited a significant seasonal variation for all the soil parameters except for SOC, SOM, and soil available potassium. Soil temperature recorded during the pre-monsoon was observed as the highest, followed by monsoon and post monsoon seasons. The bulk density ranged from 1.09g/cm^3 during the monsoon to 1.38g/cm^3 during the post monsoon period. A similar seasonal trend was observed for the soil moisture content and water holding capacity,

with maximum mean value during the monsoon, followed by post-monsoon and pre-monsoon seasons. pH value was the highest during the pre-monsoon season and the lowest during the monsoon period. The SOC and SOM content were maximum during monsoon and minimum during pre-monsoon period. The soil available nitrogen and available phosphorus exhibited the following seasonal trend– post-monsoon > monsoon > pre-monsoon. Soil available potassium content ranged from 355.9 kg/ha during post-monsoon to 366.54 kg/ha during pre-monsoon period (Table 4.3.11). The detailed results of one-way ANOVA and Tukey’s post hoc results are presented in Appendix AI and AJ.

Table 4.3.11 Mean values ($\pm$ SD) of soil parameters under Secondary Forest as affected by seasons

Soil Parameters	Seasons		
	Pre-Monsoon	Monsoon	Post-Monsoon
Temperature (°C)	29.2 $\pm$ 2.99 ^c	25.5 $\pm$ 0.52 ^a	22.1 $\pm$ 2.64 ^b
BD (g/cm ³)	1.37 $\pm$ 0.20 ^b	1.09 $\pm$ 0.09 ^a	1.38 $\pm$ 0.36 ^a
MC (%)	14.0 $\pm$ 4.83 ^c	25.7 $\pm$ 4.70 ^a	19.8 $\pm$ 3.56 ^b
WHC (%)	30.9 $\pm$ 4.03 ^b	34.3 $\pm$ 5.29 ^a	35.7 $\pm$ 2.11 ^{ab}
pH	5.17 $\pm$ 0.23 ^b	4.79 $\pm$ 0.28 ^a	5.08 $\pm$ 0.56 ^{ab}
SOC (%)	1.10 $\pm$ 0.34 ^a	0.8740 $\pm$.19 ^a	1.02 $\pm$ 0.22 ^a
SOM (%)	1.90 $\pm$ 0.59 ^a	1.51 $\pm$ 0.34 ^a	1.76 $\pm$ 0.38 ^a
AN (kg/ha)	216.11 $\pm$ 26.5 ^b	216.39 $\pm$ 3.56 ^a	239.67 $\pm$ 11.5 ^b
AP (kg/ha)	5.04 $\pm$ 1.60 ^b	7.84 $\pm$ 1.82 ^a	10.3 $\pm$ 3.71 ^a
AK (kg/ha)	355.9 $\pm$ 7.2 ^a	359.2 $\pm$ 9.8 ^a	366.54 $\pm$ 20.8 ^a

Different upper case letters are significantly different at $p < 0.05$ between seasons

The Welch’s two samples t-test revealed that soil under the secondary forest did not exhibit depth-wise difference in their temperature, bulk density, moisture content, and water holding capacity $p < 0.05$ (Figure 4.3.3).

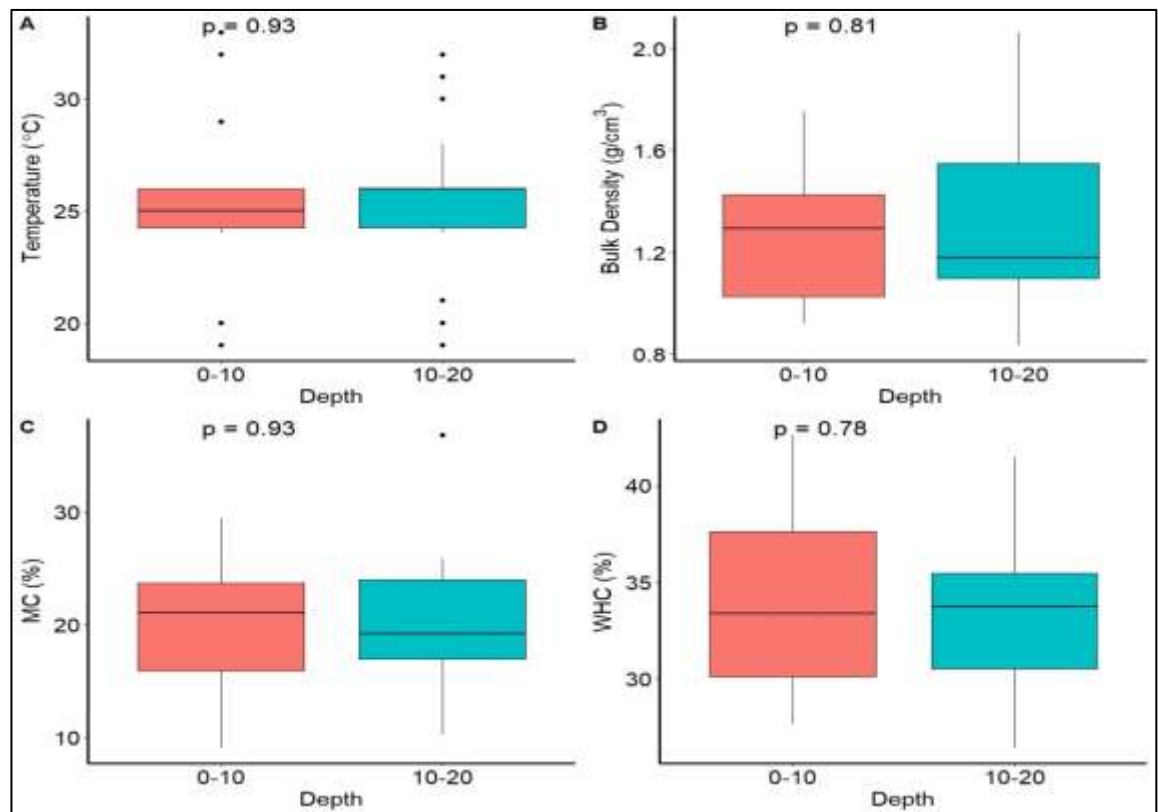


Figure 4.3.3 Box plot showing the distribution of soil (A) temperature (B) bulk density (C) moisture content (D) water holding capacity at different depths under the secondary forest

Soil under the secondary forest showed significant depth-wise difference in the SOC, SOM, and available nitrogen, phosphorus and potassium, with their mean values higher in the upper soil depth. In contrast, pH was the only parameter that did not show significant vertical variation at $p < 0.05$ (Figure 4.3.4).

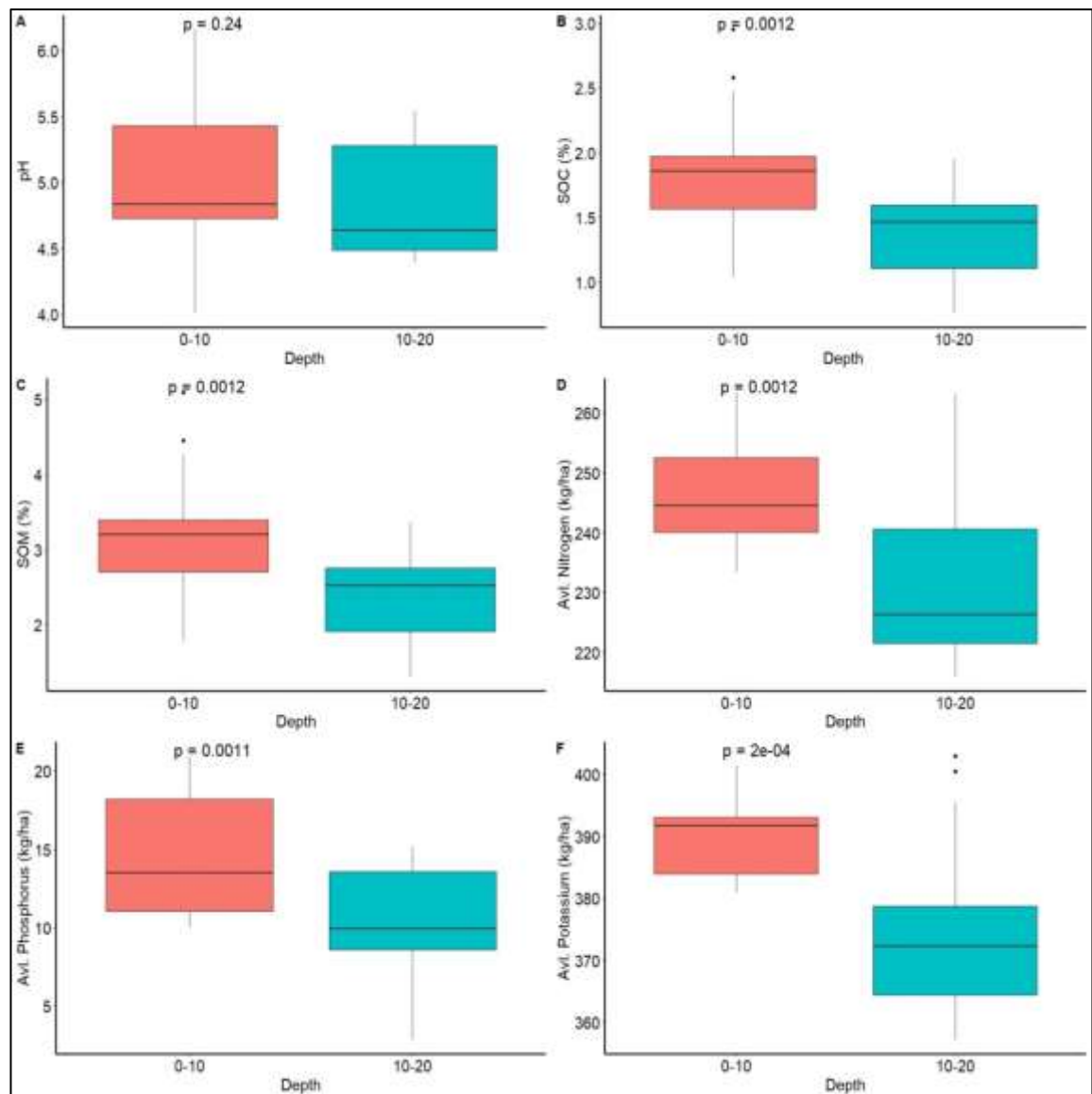


Figure 4.3.4 Box plot showing the distribution of soil soil (A) pH (B) SOC (C) SOM (D) Available nitrogen (E) Available Phosphorus (F) Available Potassium at different depths under the secondary forest

Current Jhum

The mean value of soil temperature, bulk density, pH, and available nitrogen content exhibited a significant seasonal variation, each attaining maximum values during the pre-monsoon period, decreasing through monsoon and finally reached their lowest during the post-monsoon season. In contrast soil moisture content followed an inverse trend, with its level peaking during the monsoon and reaching its lowest level during the pre-monsoon season. Soil water

holding capacity ranged from 34.2 % to 36.2 %, attaining its maximum capacity during the monsoon and post-monsoon season. Seasonal SOC and SOM were recorded maximum in the monsoon, and minimum in the post-monsoon season. Mean value of soil available phosphorus and potassium were the highest during the post monsoon season (Table 4.3.12). The detailed results of ANOVA and Tukey's post tests are presented in Appendix AK and AL.

Table 4.3.12 Mean values ($\pm$ SD) of soil parameters under Current jhum as affected by seasons

Soil Parameters	Seasons		
	Pre-Monsoon	Monsoon	Post-Monsoon
Temperature ($^{\circ}$ C)	33.8 $\pm$ 6.19 ^c	26.8 $\pm$ 0.389 ^a	22.2 $\pm$ 3.21 ^b
BD (g/cm ³)	1.47 $\pm$ 0.235 ^b	0.965 $\pm$ 0.172 ^a	1.33 $\pm$ 0.341 ^a
MC (%)	10.7 $\pm$ 1.71 ^c	26.4 $\pm$ 3.51 ^a	21.8 $\pm$ 3.49 ^b
WHC (%)	34.2 $\pm$ 2.08 ^a	36.2 $\pm$ 2.75 ^a	36.2 $\pm$ 3.30 ^a
pH	5.32 0.38 ^b	4.78 0.51 ^a	5.04 0.53 ^{ab}
SOC (%)	1.27 $\pm$ 0.36 ^a	1.38 $\pm$ 0.43 ^a	1.21 $\pm$ 0.51 ^a
SOM (%)	2.19 $\pm$ 0.62 ^a	2.38 $\pm$ 0.74 ^a	2.08 $\pm$ 0.87 ^a
AN (kg/ha)	253. $\pm$ 15.6 ^b	236. $\pm$ 11.9 ^a	240. $\pm$ 7.94 ^b
AP (kg/ha)	10.7 $\pm$ 2.00 ^a	9.12 $\pm$ 2.46 ^a	11.3 $\pm$ 3.49 ^a
AK (kg/ha)	380. $\pm$ 41.6 ^a	390. $\pm$ 20.7 ^a	394. $\pm$ 13.7 ^a

Different upper case letters are significantly different at $p < 0.05$ between seasons

The soil temperature, bulk density, moisture content, and water holding capacity did not differ significantly with depth at $p < 0.05$ in the jhum cultivation site (Figure 4.3.5)

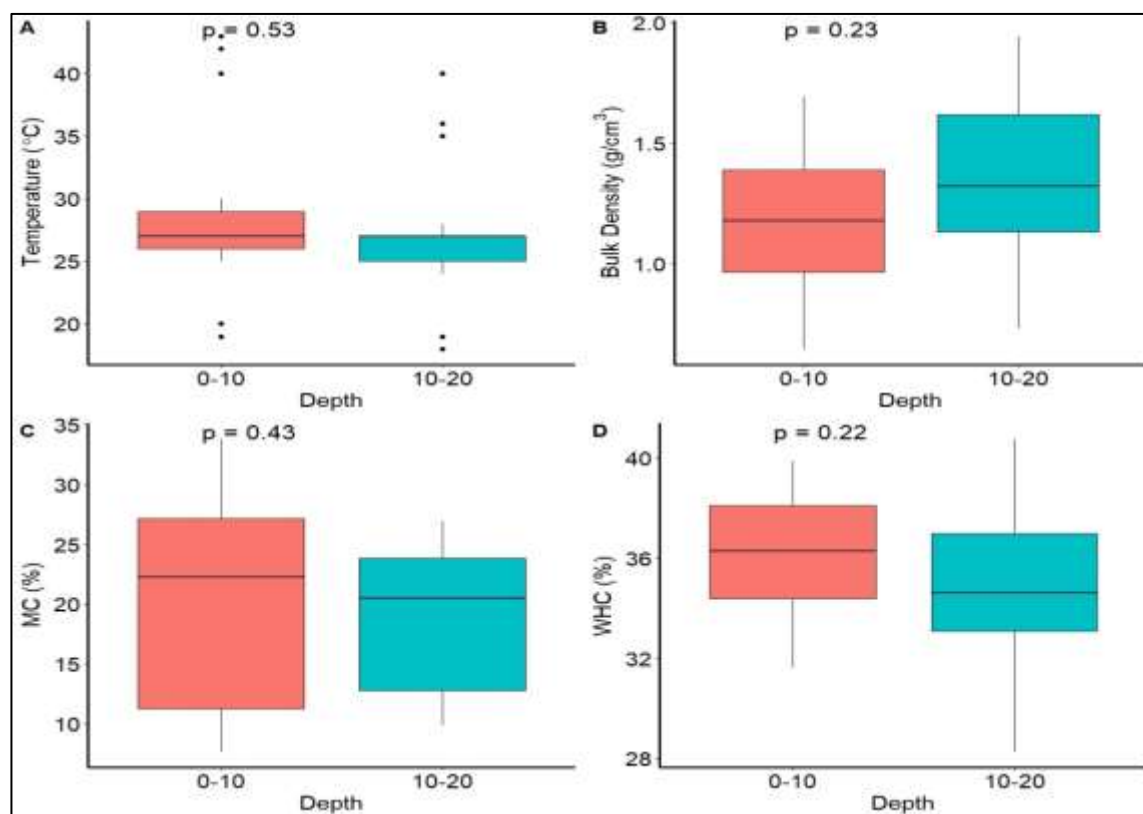


Figure 4.3.5 Box plot showing the distribution of soil (A) temperature (B) bulk density (C) moisture content (D) water holding capacity at different depths at the jhum

Under the jhum cultivation site, mean values of soil parameters such as SOC, SOM, available N, P and K were significantly higher in the 0 – 10 cm soil depth at $p < 0.05$, while the vertical distribution of soil pH value remained relatively uniform (Figure 4.3.6).

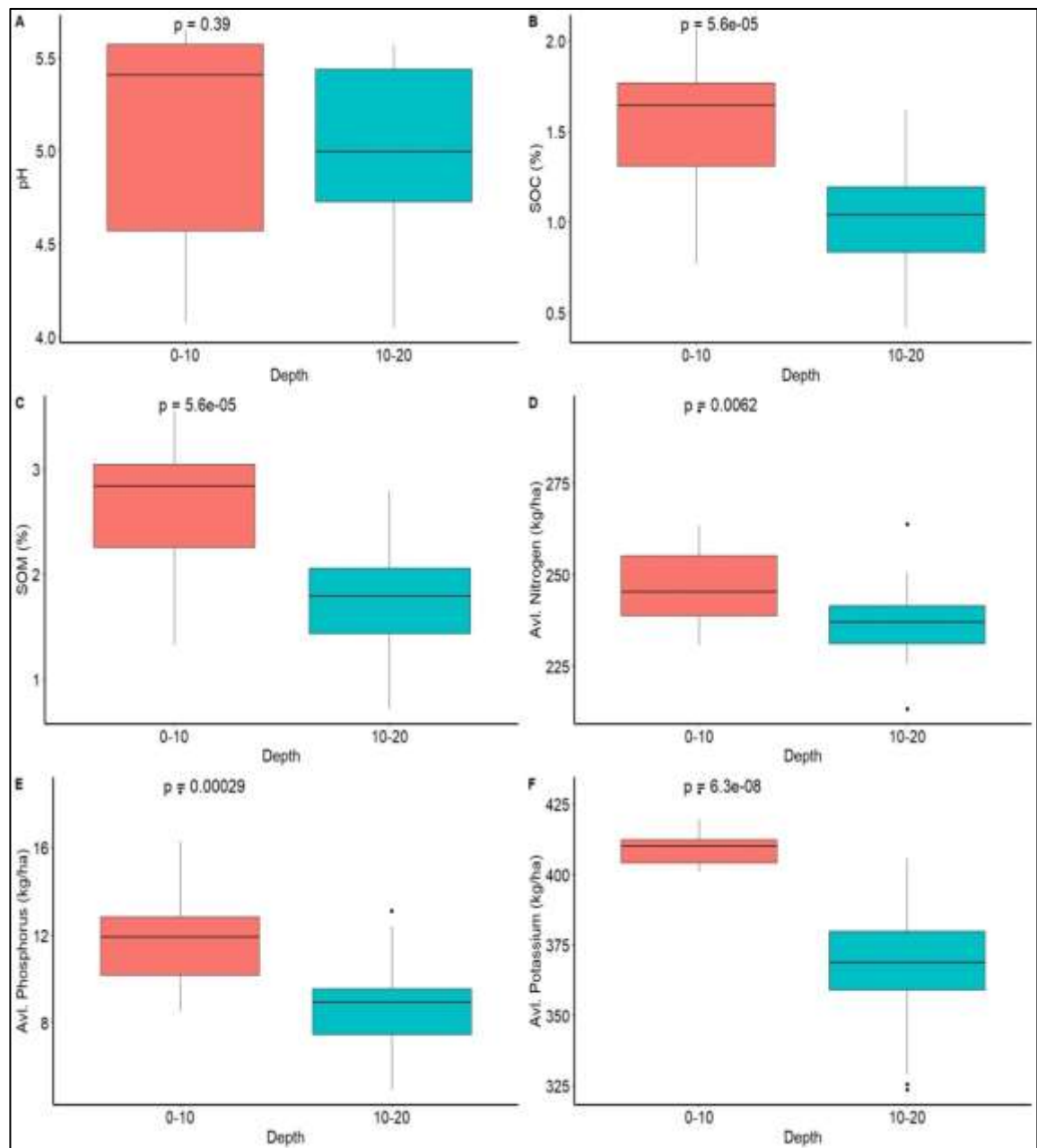


Figure 4.3.6 Box plot showing the distribution of soil soil (A) pH (B) SOC (C) SOM (D) Available Nitrogen (E) Available Phosphorus (F) Available Potassium at different depths under the

Oil palm

Soil under oil palm plantation exhibited a clear seasonal trend in temperature with peaked temperature recorded during the pre-monsoon, and declined during the monsoon and attained lowest temperature during the post monsoon season. Bulk

density was significantly lower during the monsoon and increased during the pre-monsoon and post-monsoon period. Soil moisture content and water holding capacity were maximum during the monsoon and minimum during the pre-monsoon period. Mean pH value, SOC, and SOM content were the highest during pre-monsoon, followed by monsoon and post monsoon season. Soil macronutrients exhibited distinct seasonal trend, with available nitrogen and potassium peaking during the monsoon, while available phosphorus reached maximum level in the post monsoon season (Table 4.3.13). The detail results of one-way ANOVA and Tukey's post hoc tests are presented in Appendix AM and AN.

Table 4.3.13 Mean values ($\pm$ SD) of soil parameters under Oil Palm as affected by seasons

Soil Parameters	Seasons		
	Pre-Monsoon	Monsoon	Post-Monsoon
Temperature ($^{\circ}$ C)	27.5 1.98 ^b	25.2 0.71 ^a	21.9 3.96 ^a
BD (g/cm ³)	1.32 $\pm$ 0.26 ^b	1.13 $\pm$ 0.14 ^a	1.47 $\pm$ 0.38 ^{ab}
MC (%)	10.9 3.59 ^c	26.5 3.83 ^a	20.5 5.46 ^b
WHC (%)	31.3 $\pm$ 1.91 ^a	31.4 $\pm$ 4.16 ^a	34.0 $\pm$ 2.11 ^a
pH	5.33 0.64 ^b	4.73 $\pm$ 0.53 ^a	5.1 $\pm$ 0.4 ^{ab}
SOC (%)	1.25 $\pm$ 0.47 ^a	0.983 $\pm$ 0.26 ^a	0.914 $\pm$ 0.34 ^a
SOM (%)	2.16 $\pm$ 0.81 ^a	1.69 $\pm$ 0.44 ^a	1.58 $\pm$ 0.58 ^a
AN (kg/ha)	218.53 $\pm$ 20.6 ^a	232.36 $\pm$ 7.56 ^a	227.70 $\pm$ 13.5 ^a
AP (kg/ha)	5.43 $\pm$ 3.41 ^b	8.18 $\pm$ 2.98 ^a	11.2 $\pm$ 3.14 ^{ab}
AK (kg/ha)	330.27 $\pm$ 4.86 ^b	360.35 $\pm$ 21.9 ^a	327.26 $\pm$ 12.1 ^b

Different upper case letters are significantly different at $p < 0.05$ between seasons

Under the oil palm cultivation site, none of the measured soil physical parameters exhibited significant difference along the soil profile at $p < 0.05$ (Figure 4.3.7).

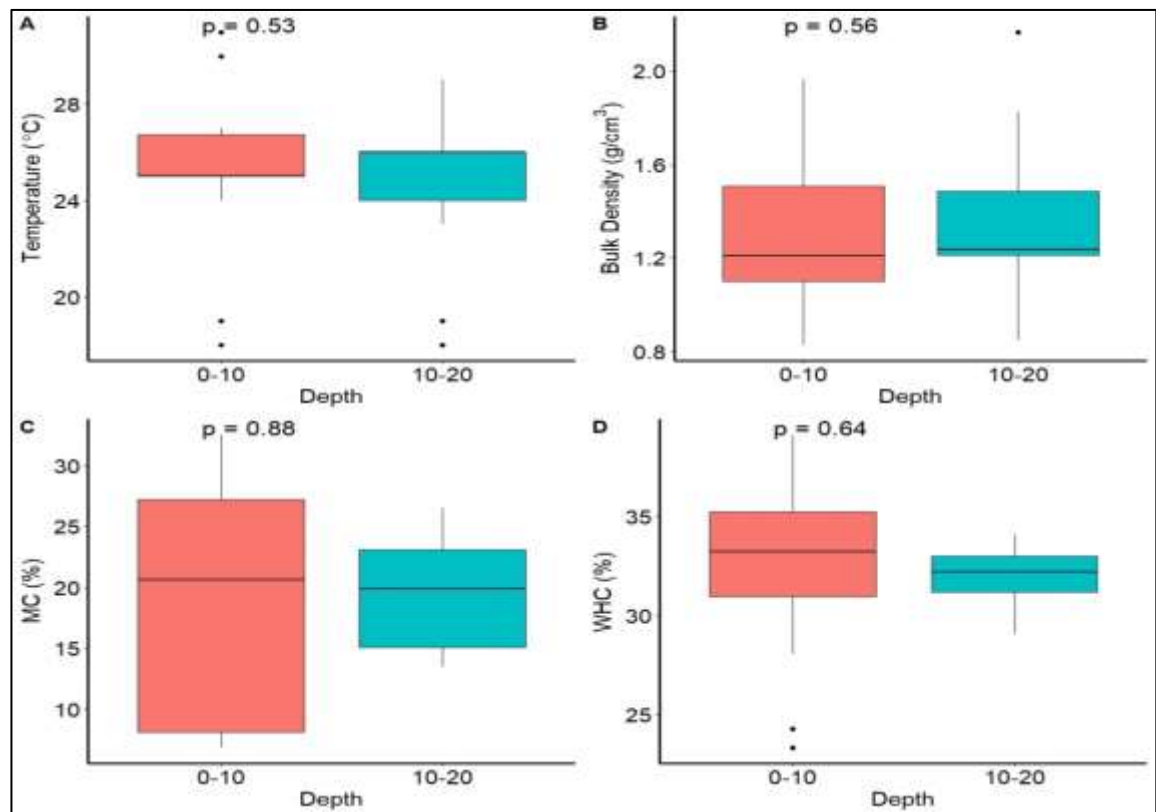


Figure 4.3.7 Box plot showing the distribution of soil (A) temperature (B) bulk density (C) moisture content (D) water holding capacity at different depths under the oil palm plantation

The mean values of soil pH, SOC, SOM, and available nitrogen, phosphorus and potassium were significantly higher in the upper soil depth compared to the lower soil under the oil palm cultivation site at $p < 0.05$ (Figure 4.3.8).

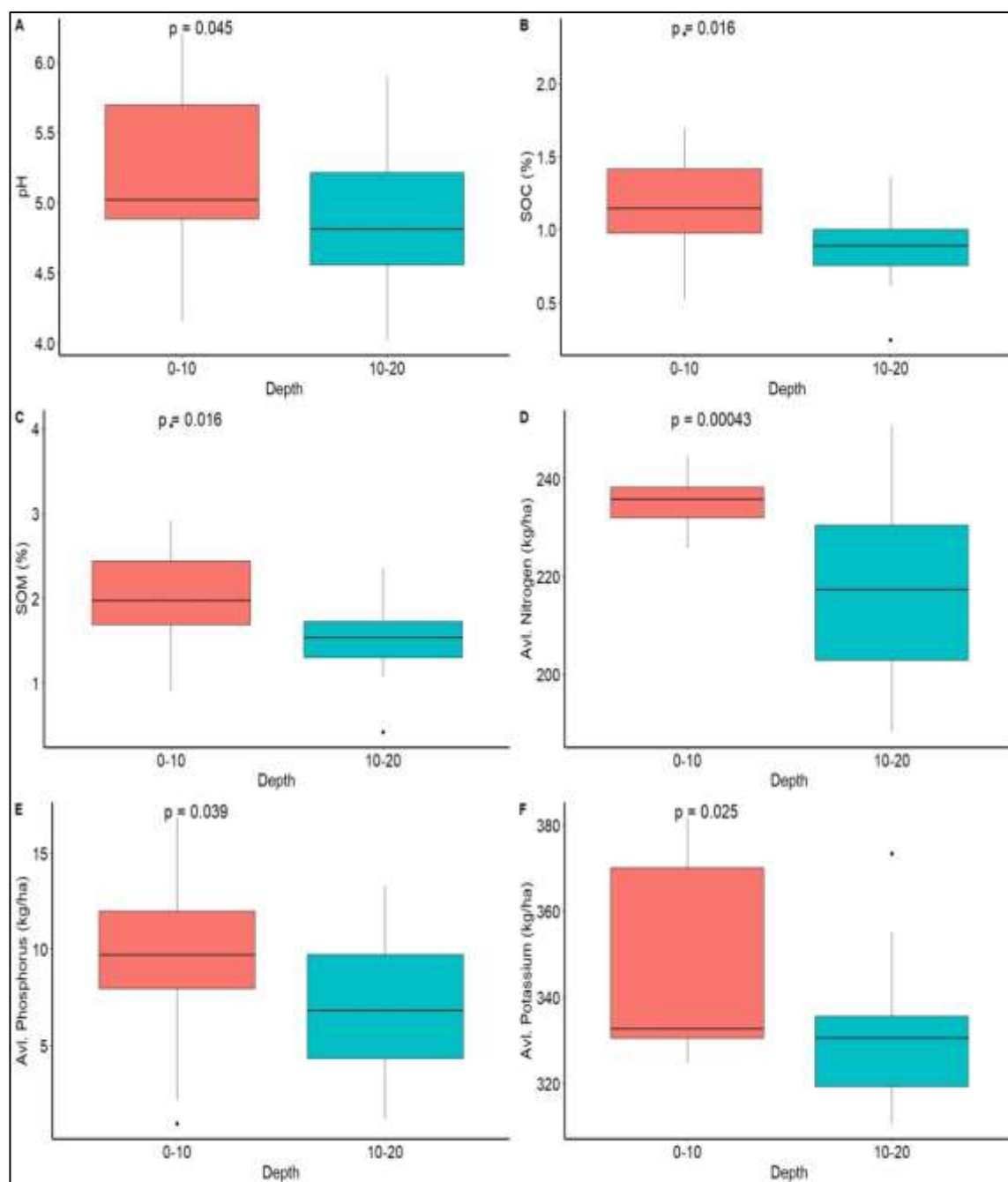


Figure 4.3.8 Box plot showing the distribution of soil (A) pH (B) SOC (C) SOM (D) Available Nitrogen (E) Available Phosphorus (F) Available Potassium at different depths under the oil palm plantation site

Teak

Soil under the teak plantation exhibited significant seasonal variation for each parameter at $p < 0.05$. Temperature was the highest during the pre-monsoon, followed by the monsoon and post-monsoon season. Soil bulk density was the

maximum during the post-monsoon and minimum in the monsoon period. Soil moisture content peaked during the monsoon season, and declined with post monsoon and reached its minimum in the pre-monsoon season. In contrast, soil water holding capacity was highest during the post-monsoon and the lowest in the monsoon period. Mean pH value was the highest in the post-monsoon, followed by the pre-monsoon and monsoon season. The SOC and SOM followed a consistent seasonal trend- pre-monsoon > monsoon > post monsoon. The soil available nitrogen and phosphorus content peaked during the post-monsoon season, whereas the available potassium was the highest in the monsoon season (Table 4.3.14). The detail results of the one-way ANOVA and Tukey's post hoc tests are presented in Appendix AO & AP.

Table 4.3.14 Mean values ($\pm$ SD) of soil parameters under Teak as affected by seasons

Soil Parameters	Seasons		
	Pre-Monsoon	Monsoon	Post-Monsoon
Temperature ($^{\circ}$ C)	28.4 $\pm$ 1.93 ^c	25.5 $\pm$ 0.52 ^a	22.1 $\pm$ 2.78 ^b
BD (g/cm ³)	1.45 $\pm$ 0.33 ^b	1.15 $\pm$ 0.15 ^a	1.47 $\pm$ 0.25 ^a
MC (%)	7.07 $\pm$ 1.66 ^a	23.6 $\pm$ 2.44 ^a	20.2 $\pm$ 9.59 ^b
WHC (%)	29.4 $\pm$ 2.41 ^b	28.4 $\pm$ 6.39 ^a	33.1 $\pm$ 2.11 ^{ab}
pH	5.13 $\pm$ 0.36 ^b	5.01 $\pm$ 0.29 ^a	5.62 $\pm$ 0.13 ^b
SOC (%)	1.17 $\pm$ 0.55 ^b	0.831 $\pm$ 0.36 ^a	0.662 $\pm$ 0.41 ^{ab}
SOM (%)	2.02 $\pm$ 0.95 ^b	1.43 $\pm$ 0.64 ^a	1.14 $\pm$ 0.70 ^{ab}
N (kg/ha)	205.27 $\pm$ 13.8 ^b	201.84 $\pm$ 8.80 ^a	223.94 $\pm$ 11.7 ^b
P (kg/ha)	4.38 $\pm$ 2.26 ^b	8.21 $\pm$ 1.54 ^a	9.38 $\pm$ 1.28 ^a
K (kg/ha)	323.11 $\pm$ 19.7 ^b	340.38 $\pm$ 11.4 ^a	316.88 $\pm$ 13.5 ^b

Different upper case letters are significantly different at $p < 0.05$ between seasons

Under the teak plantation site, t-test revealed that there was no significant depth-wise variation in soil temperature, bulk density, moisture content, and water holding capacity ($p < 0.05$) (Figure 4.3.9.).

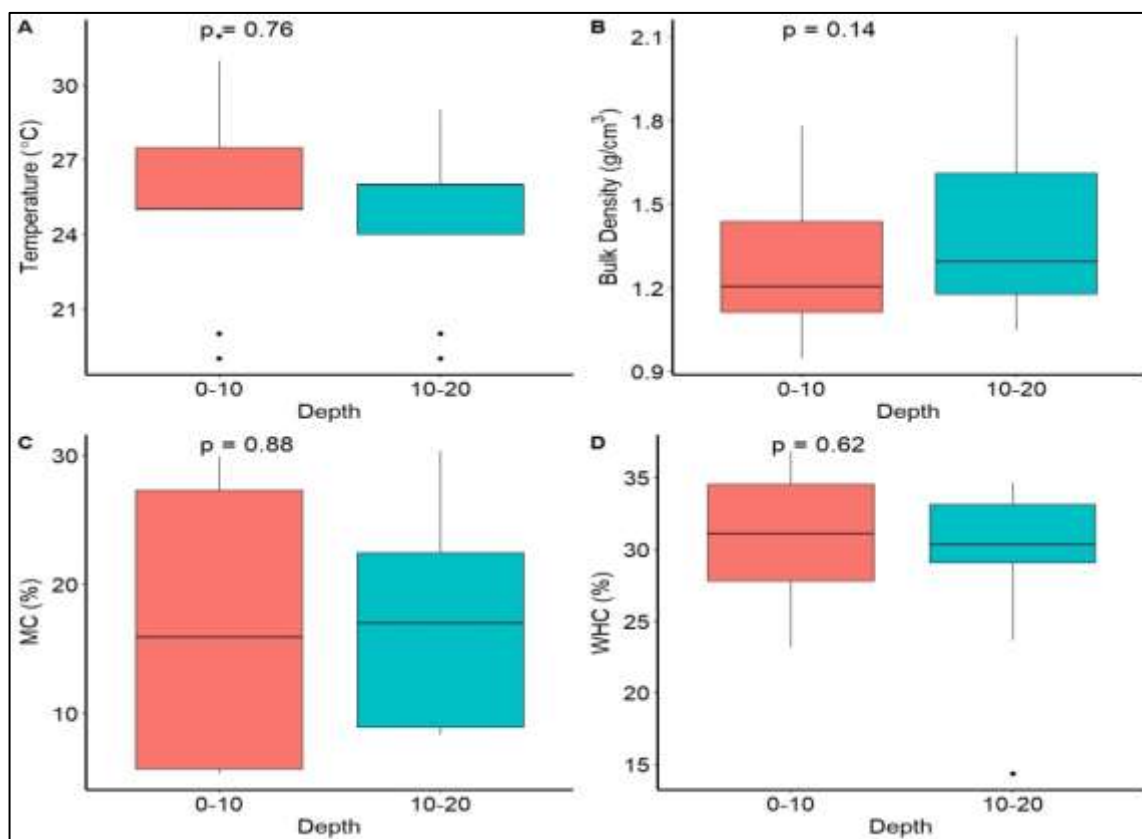


Figure 4.3.9 Box plot showing the distribution of soil (A) temperature (B) bulk density (C) moisture content (D) water holding capacity at different depths under the teak plantation site

Among the measured soil chemical parameters, only available nitrogen showed significant vertical differences with higher mean value in the upper soil under the teak plantation site ($p < 0.05$). In contrast, the other parameters remained relatively consistent with depth (Figure 4.3.10).

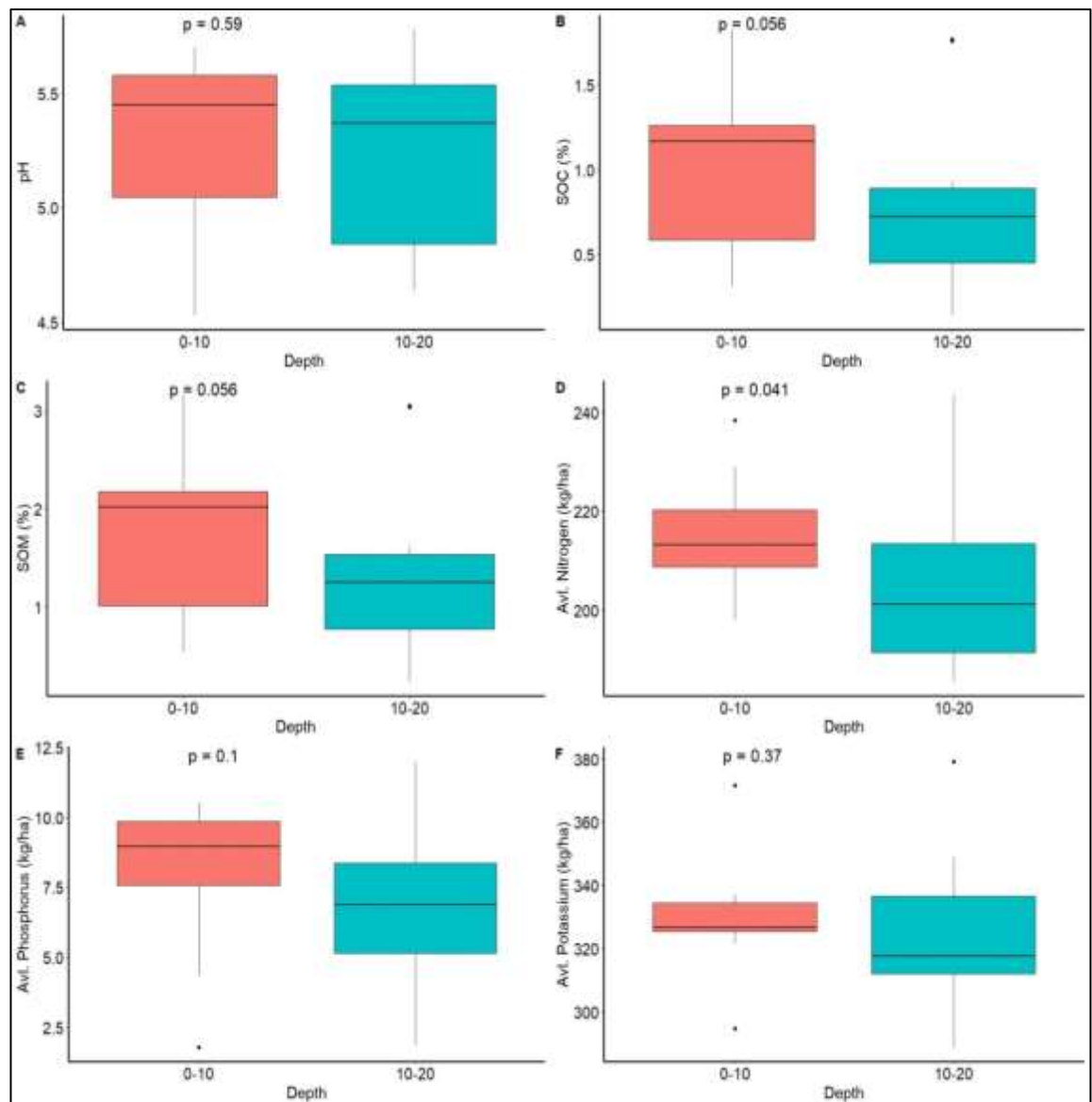


Figure 4.3.10 Box plot showing the distribution of soil soil (A) pH (B) SOC (C) SOM (D) Available Nitrogen (E) Available Phosphorus (F) Available Potassium at different depths under the teak plantation site

Areca nut

In areca nut plantation site, all the soil parameters showed a significant seasonal variation except for water holding capacity and pH. Soil temperature reached the highest value during the pre-monsoon, and decreased significantly through the monsoon and post monsoon season. The pre-monsoon season recorded the maximum bulk density, whereas the minimum value was recorded during the

monsoon season. Soil under areca nut plantation exhibited the highest moisture content in the monsoon season, followed by post-monsoon and pre-monsoon seasons. The soil was acidic in reaction, with the mean seasonal pH value ranging from 5.88 to 5.02. The SOC and SOM content were the highest during the pre-monsoon and the lowest during the monsoon season. Soil available nitrogen and phosphorus showed a similar seasonal trend, with the highest content of these nutrients recorded during the post-monsoon season and the lowest during the pre-monsoon season. On the other hand, the available potassium content peaked during the monsoon and reached its lowest value during the pre-monsoon season (Table 4.3.15). Detailed results of one-way ANOVA and Tukey's post hoc tests are presented in Appendix AQ & AR. Table 4.3.15 Mean values ($\pm$ SD) of soil parameters under Areca Nut as affected by seasons

Soil Parameters	Seasons		
	Pre-Monsoon	Monsoon	Post-Monsoon
Temperature ($^{\circ}$ C)	28.8 $\pm$ 2.30 ^c	25.5 $\pm$ 0.52 ^a	22.9 $\pm$ 3.09 ^b
BD (g/cm ³)	1.39 $\pm$ 0.29 ^b	1.03 $\pm$ 0.18 ^a	1.47 $\pm$ 0.27 ^a
MC (%)	11.0 $\pm$ 2.59 ^c	27.5 $\pm$ 3.48 ^a	22.4 $\pm$ 6.94 ^b
WHC (%)	34.7 $\pm$ 2.44 ^a	34.5 $\pm$ 4.44 ^a	34.2 $\pm$ 3.39 ^a
pH	5.02 $\pm$ 0.45 ^a	4.88 $\pm$ 0.19 ^a	5.00 $\pm$ 0.44 ^a
SOC (%)	1.22 $\pm$ 0.32 ^b	0.801 $\pm$ 0.34 ^a	1.00 $\pm$ 0.49 ^{ab}
SOM (%)	2.11 $\pm$ 0.56 ^b	1.38 $\pm$ 0.58 ^a	1.72 $\pm$ 0.84 ^{ab}
AN (kg/ha)	221.08 $\pm$ 13.9 ^b	222.81 $\pm$ 9.92 ^a	236.57 $\pm$ 8.97 ^b
AP (kg/ha)	5.10 $\pm$ 1.52 ^b	5.58 $\pm$ 1.97 ^a	8.90 $\pm$ 0.65 ^b
AK (kg/ha)	335.35 $\pm$ 14.9 ^c	368.35 $\pm$ 8.70 ^a	351.86 $\pm$ 13.7 ^b

Different upper case letters are significantly different at $p < 0.05$ between seasons

The measured soil physical properties under the areca nut plantation did not differ significantly with depth at $p < 0.05$ (Figure 4.3.11.)

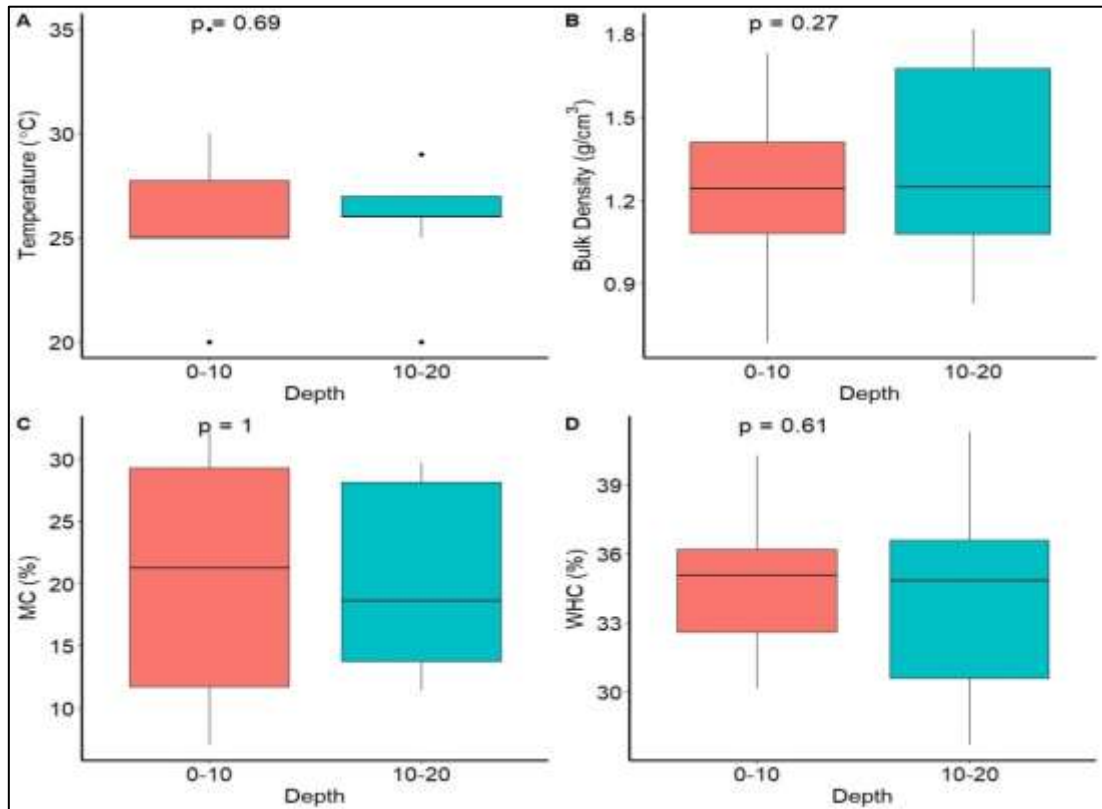


Figure 4.3.11 Box plot showing the distribution of (A) temperature (B) bulk density (C) moisture content (D) water holding capacity at different depths under the areca nut plantation site

SOC, SOM, available nitrogen and potassium revealed significant depth-wise differences, with higher mean values observed in the upper depth. In contrast, pH and available phosphorus did not show significant vertical differences ($p < 0.05$) (Figure 4.3.12).

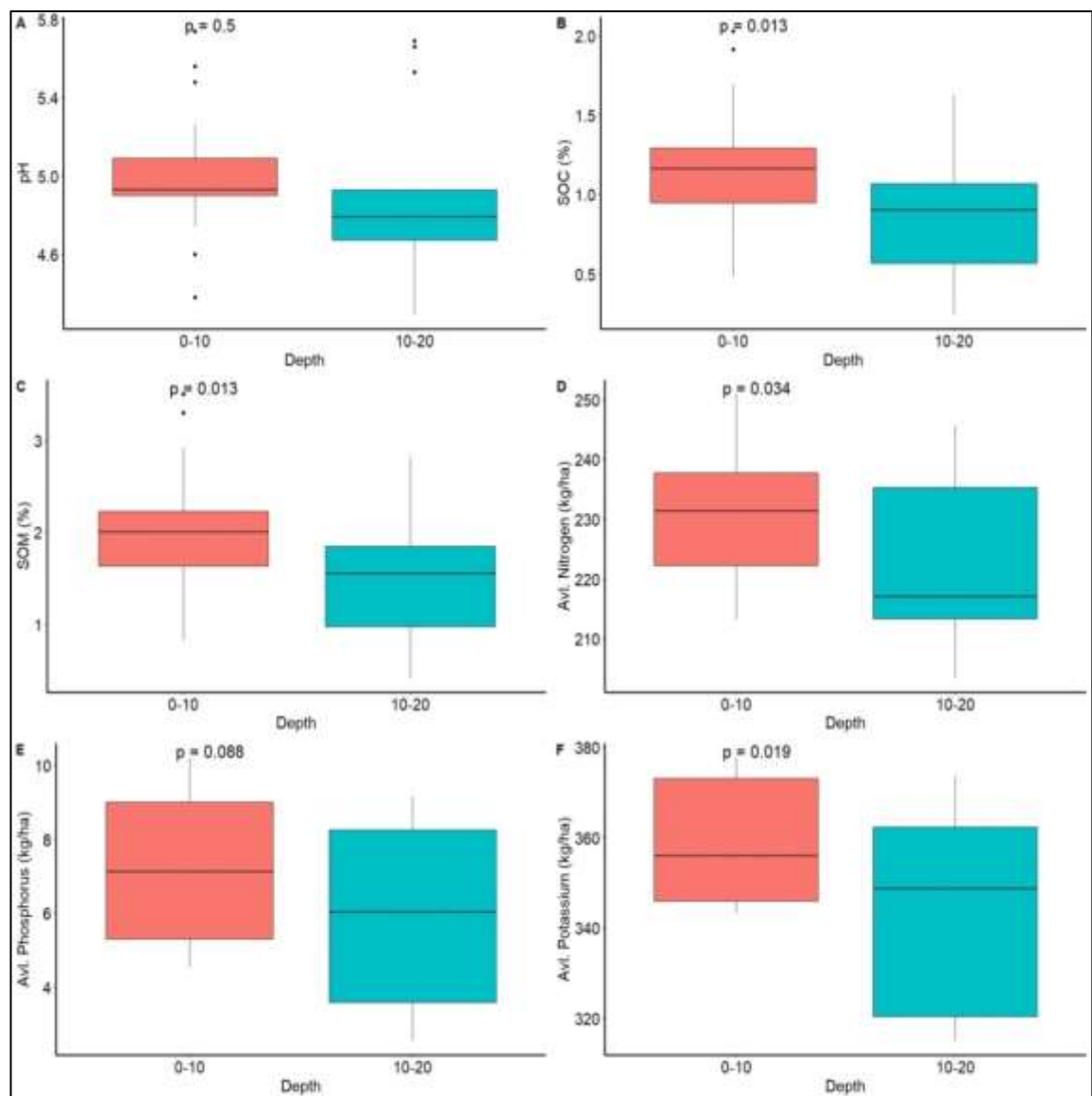


Figure 4.3.12 Box plot showing the distribution of soil (A) pH (B) SOC (C) SOM (C) Available Nitrogen (E) Available Phosphorus (F) Available Potassium at different depths under the areca nut plantation site

4.3.3. Correlation between the soil parameters

To assess the relationship between the measured soil parameters, Pearson's correlation test was performed. Significant positive correlation was observed between temperature and SOC and SOM, whereas temperature was found to have negative correlation with moisture content, water holding capacity, and phosphorus. Bulk density was negatively correlated with moisture content, SOC, SOM, and available potassium. Significant positive relationship was observed between WHC and SOC, SOM, and available nitrogen, phosphorus, and potassium. A strong significant positive relationship was observed between SOC and SOM. In addition SOC and SOM were found to have a significant relationship with available N, P, and K. The measured available macronutrients (N, P, and K) exhibited significant positive correlation among themselves (Figure 4.3.13).

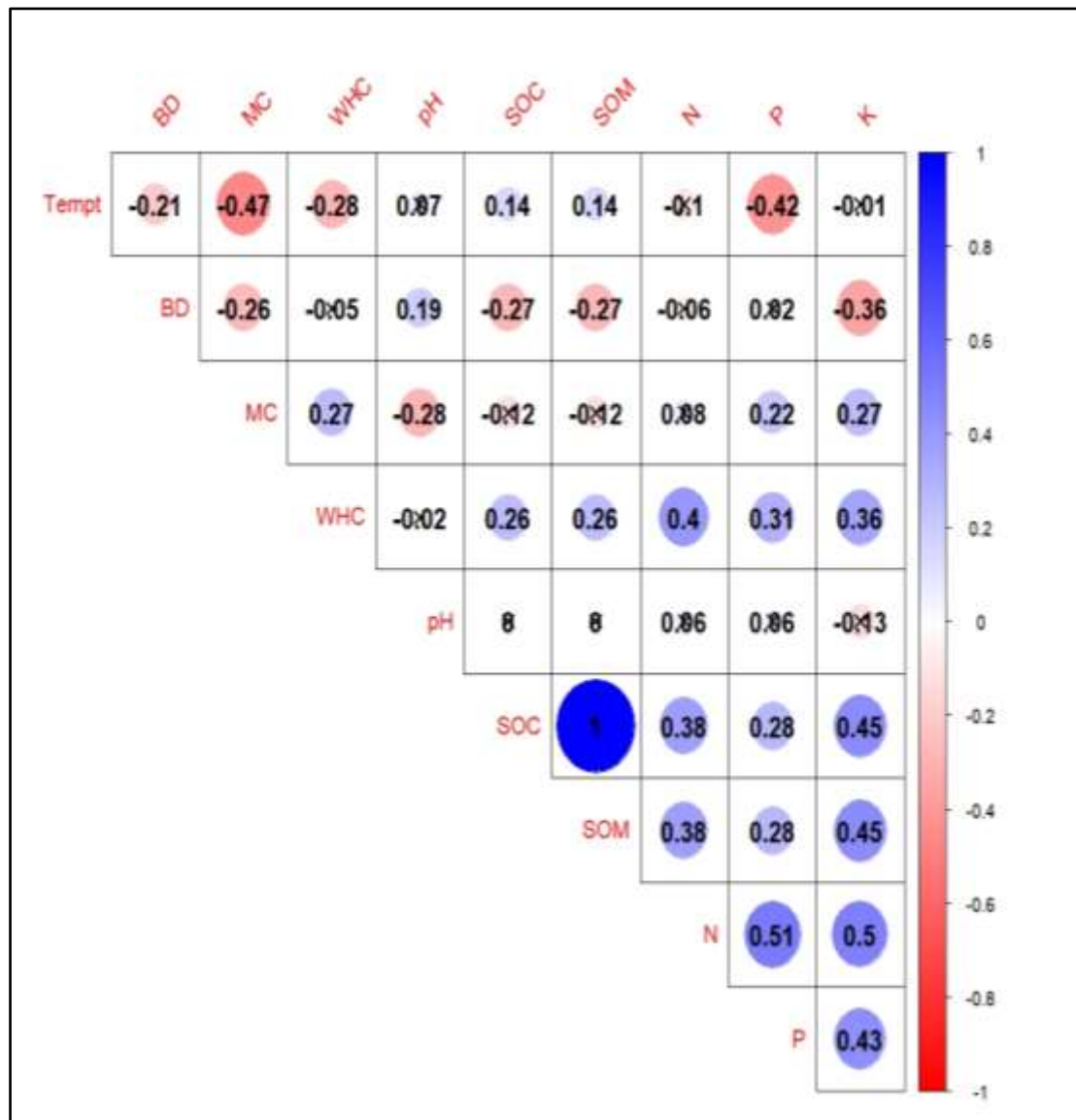


Figure 4.3.13 Pearson's correlation matrix showing relationship between the different soil parameters. Circle size and color indicate correlation strength and direction (blue: positive, red: negative); numeric values represent correlation coefficients.

4.3.4. Soil Quality Index (SQI)

Minimum Dataset (MDS)

PCA was conducted to extract indicators as minimum dataset for evaluating the SQI. The test summary is presented in Table 4.3.16; PC1, PC2, and PC3 were considered for further evaluation, as they had eigenvalue greater than 1 and explained 68.68 % of variation in the data. Available phosphorus with a factor loading of 0.79 constituted the highest 10% factor loading in PC1. SOC (0.94) and SOM (0.94) were the highest 10% factor loading in PC2, however, only SOC was retained due to the strong correlation between the two. Additionally, in PC3, pH with a factor loading of 0.71 was selected.

Table 4.3.16 Principal components, eigenvalues and component matrix variables

Principal Components	PC1	PC2	PC3
Eigenvalues	3.23	1.59	1.36
% Variance	35.90	17.67	15.12
%Cumulative Variance	35.90	53.56	68.68
Factor Loadings			
BD	0.06	-0.39	0.69
MC	0.42	-0.34	-0.67
WHC	0.68	0.07	-0.09
pH	0.08	0.03	0.71
SOC	0.24	0.94	-0.02
SOM	0.24	0.94	-0.02
AN	0.76	0.26	0.10
AP	0.79	0.09	0.08
AK	0.60	0.40	-0.37

Boldface factor loadings were considered highly weighted and retained in the MDS

Dimensionality reduction identified a key set of variables, narrowing the nine parameters to a minimum dataset comprising available P, SOC, and pH (Figure 4.3.14.). SQI was calculated after transforming the variables in the MDS using linear scoring functions.

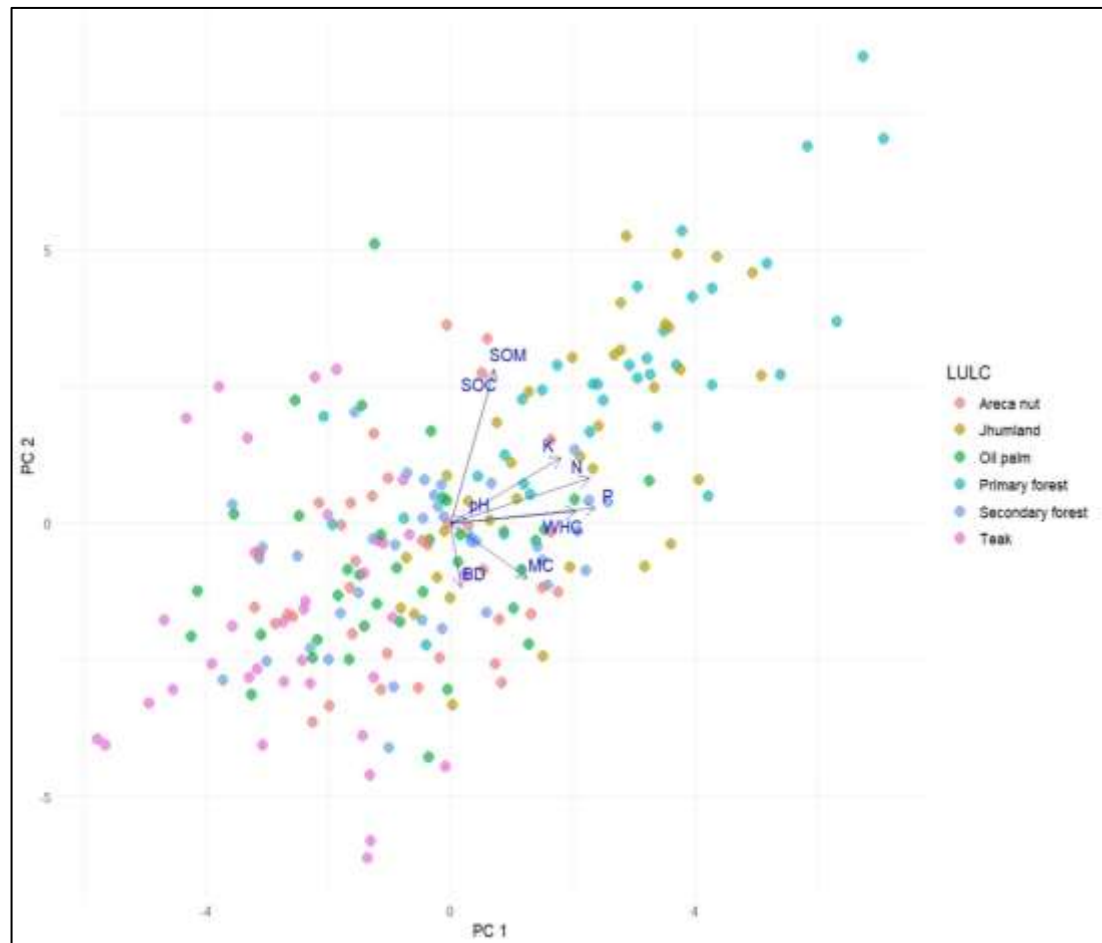


Figure 4.3.14 Principal Component Analysis (PCA) biplot based on soil physicochemical parameters used for Soil Quality Index (SQI) for determining soil quality under each land use system

SQI at 0-20 cm soil depth

The mean additive SQI at the overall soil depth was the highest under the natural forest (0.90) during the post-monsoon season, followed by the secondary forest (0.89), and the areca nut plantation (0.88). While majority of the land use types recorded the maximum SQI during the post-monsoon season, the current jhum recorded its peak SQI (0.83) during the pre-monsoon season. The seasonal SQI pattern revealed that the values were the lowest during monsoon season except for the teak plantation which recorded the minimum SQI (0.70) during the pre-monsoon season (Figure 4.3.15).

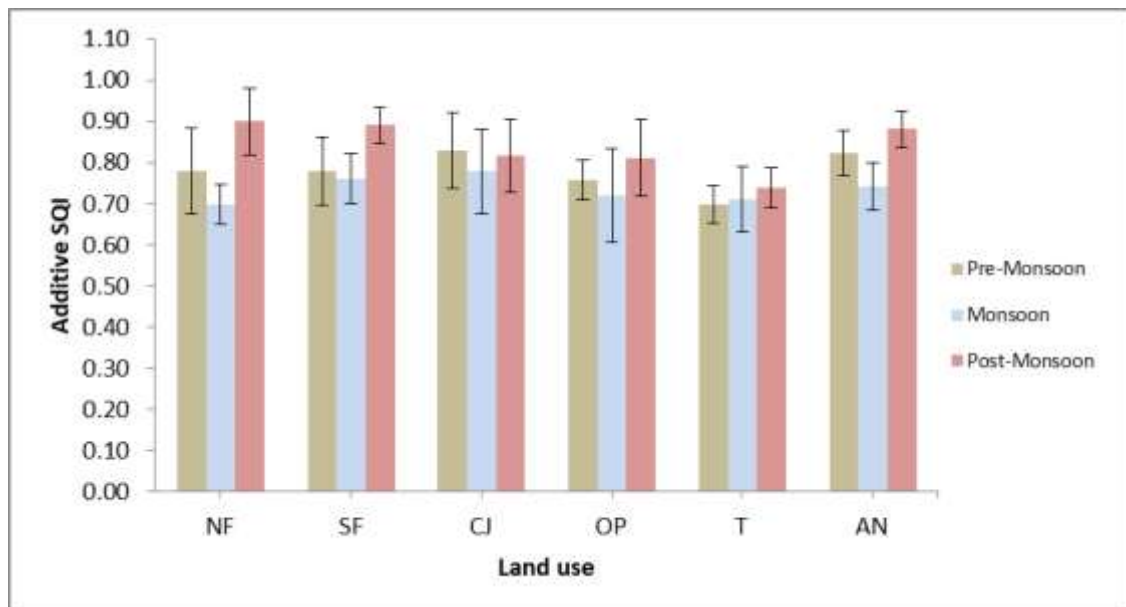


Figure 4.3.15 Seasonal additive SQI (0 – 20 cm) across the land use types

The weighted SQI at 0-20 cm followed a similar pattern as that of the additive SQI, with maximum weighted SQI reported from the natural forest at 0.90 during the post-monsoon period, followed by the secondary forest (0.89), and the areca nut plantation at (0.87) (Figure 4.3.16).

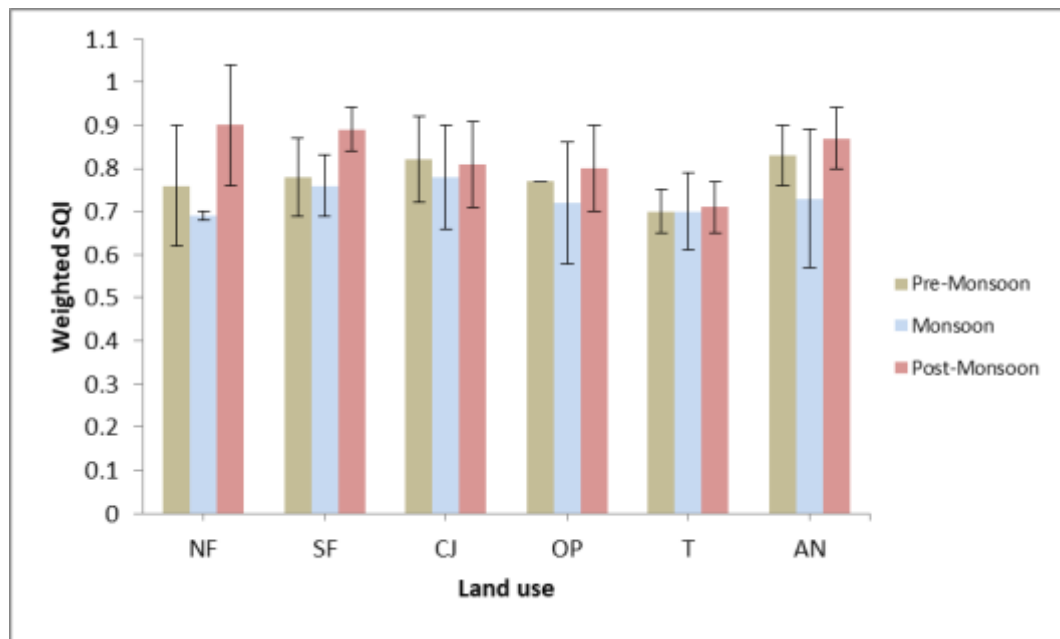


Figure 4.3.16 Seasonal weighted SQI (0 – 20 cm) across the land use types

SQI at 0 – 10 cm soil depth

The maximum additive SQI at the 0 – 10 cm soil under NF, SF, OP, and AN was observed in the post-monsoon season. Whereas, CJ and T exhibited the highest SQI value in the pre-monsoon and monsoon season respectively (Figure 4.3.17).

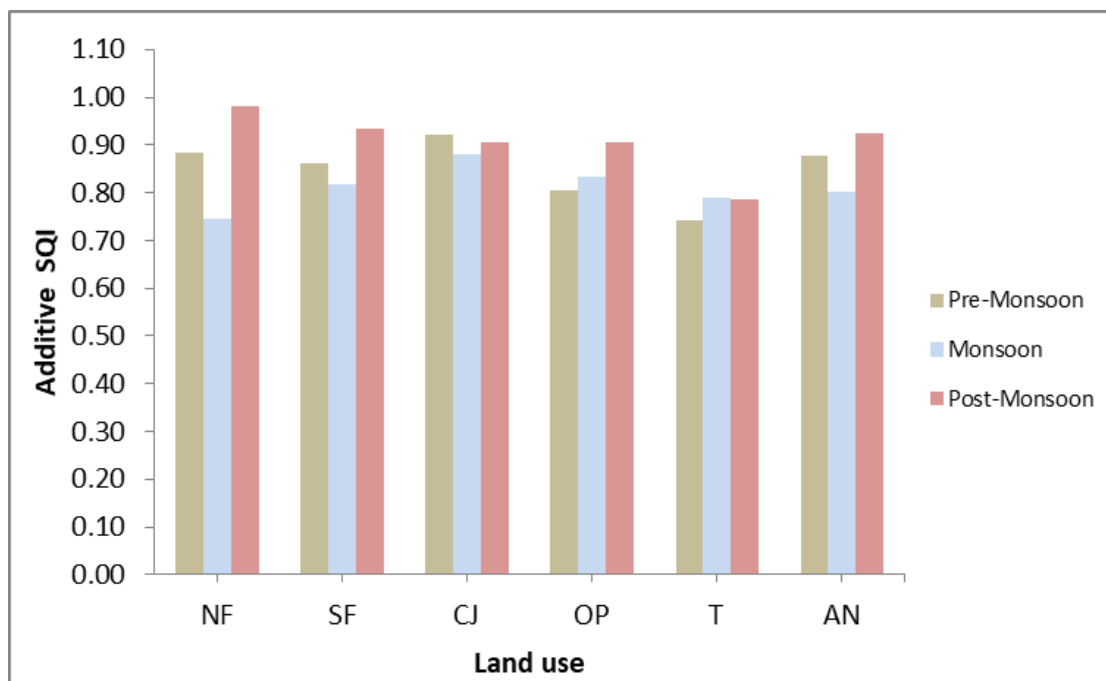


Figure 4.3.17 Seasonal additive SQI (0 – 10 cm) across the land use types

The weighted SQI values under NF, SF, OP, and AN were the highest during the post monsoon. Whereas, CJ and T recorded maximum value in the pre-monsoon and monsoon respectively. The seasonal SQI values were relatively consistent for the jhum and teak plantation sites, while a notable increase in SQI was observed in the natural forest in the post monsoon season (Figure 4.3.18).

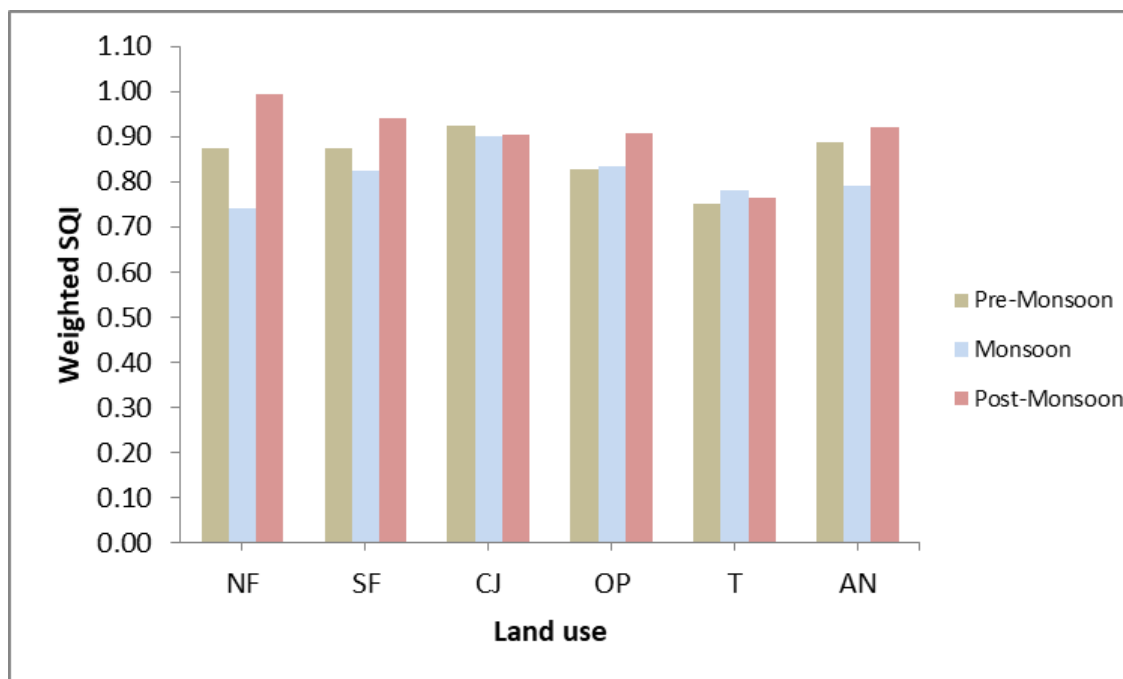


Figure 4.3.18 Seasonal weighted SQI (0 – 10 cm) across the land use types

SQI at 10 – 20 cm depth

The seasonal additive SQI values at the 10 – 20 cm soil depth under each land use system, with the exception of the current jhum were the highest in the post monsoon period, followed by the pre-monsoon and monsoon season. A notable increase in the SQI was observed during the post monsoon season for the natural and secondary forest, and the areca nut plantation site (Figure 4.3.19).

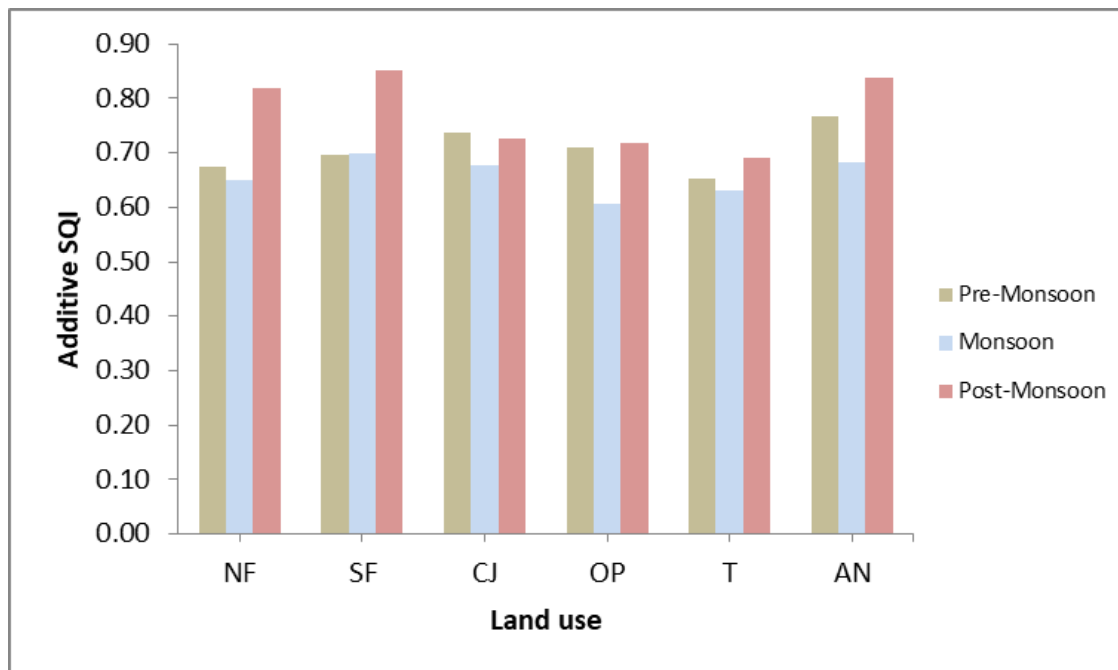


Figure 4.3.19 Seasonal additive SQI at 10 – 20 cm depth across the land use types

Weighted SQI values in NF, SF, and AN peaked during the post-monsoon season, whereas maximum values in CJ, OP, and T were recorded in the pre-monsoon season at the 10- 20 cm soil depth. Additionally, in the NF, SF, and AN, a notable rise in SQI was observed in the post-monsoon season. Monsoon season recorded the lowest SQI values across all land use systems with the exception of the secondary forest site (Figure 4.3.20).

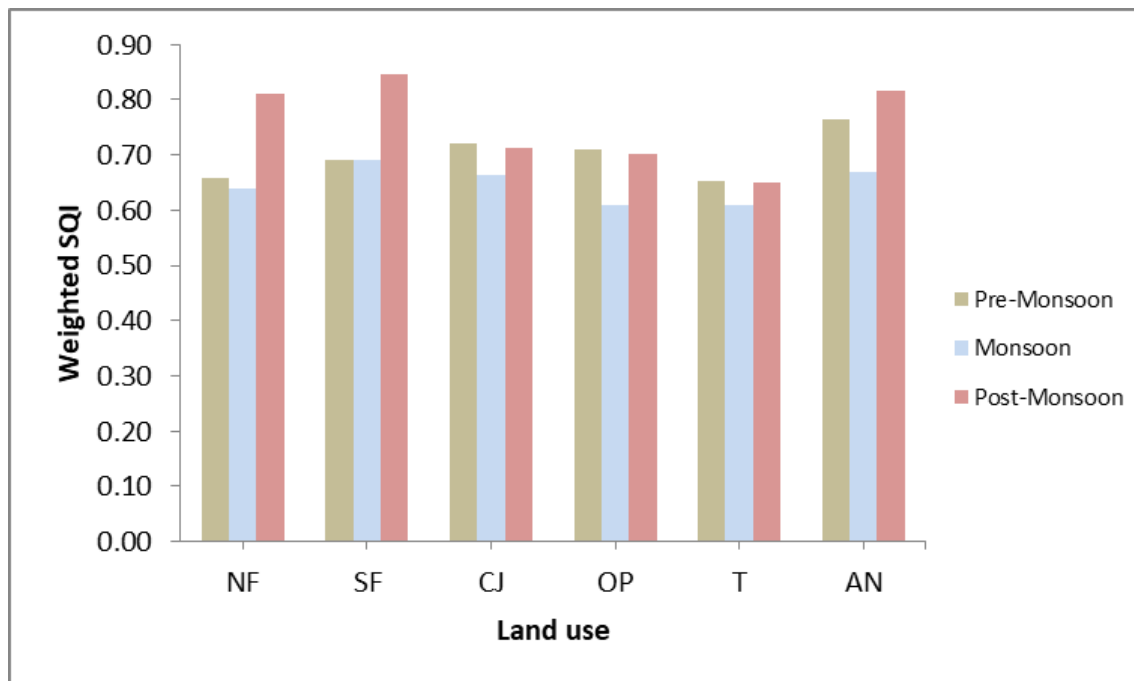


Figure 4.3.20 Seasonal weighted SQI (10 – 20cm) across the land use types

4.4. Tree diversity and community characteristics

A total of 91 tree species representing 39 families were recorded from the natural forest in the core zone. Individual species in the core zone are presented in Table 4.4.1, *Schima wallichii* represented by 20 individuals was the most abundant species, followed by *Macropanax undulatus* with 19 individuals, *Mesua ferrea* with 17 individuals, *Syzygium cumini* with 15 individuals, *Syzygium claviflorum* with 10 individuals and 10 individual stands of *Castanopsis tribuloides*. Species ecological dominance were assessed based on their IVI and the results revealed that *Schima wallichii* with an IVI value of 17.9 was the most important species, followed by *Mesua ferrea* (12.33), *Syzygium cumini* (11.93), *Macropanax undulatus* (10.61), and *Magnolia oblonga* (10.59) (Table 4.4.1). Family Importance Value Index (FIVI) revealed that Combretaceae (FIVI= 24.15) was the most ecologically dominant family, followed by Lauraceae with an FIVI value of 21.4, Theaceae and Myrtaceae with an FIVI of 20.8 and 20.55 respectively (Table 4.4.2).

Table 4.4.1 Phytosociological attributes of tree species in the natural forest (core zone)

Species	Frequency (%)	Density (stem/ha)	BA (m ² /ha)	IVI	A/F
<i>Acrocarpus fraxinifolius</i> Wight & Arn.	10	2.5	0.09	1.82	C
<i>Acronychia pedunculata</i> (L.) Miq.	5	1.25	0.03	0.88	C
<i>Actinodaphne obovata</i> (Nees) Blume	10	2.5	0.03	1.69	C
<i>Adenanthera pavonina</i> (Linn.)	5	2.5	0.06	1.25	C
<i>Aglaia spectabilis</i> (Miq.) S.S.Jain & S.Bennet	20	5	0.21	3.73	RA
<i>Ailanthus integrifolia</i> Lam	15	2.5	0.16	2.50	RA
<i>Albizia lebbek</i> (L.) Benth.	5	2.5	0.38	2.04	C
<i>Alphonsea ventricosa</i> (Roxb.) Hk.f & Th	10	3.75	0.19	2.37	C
<i>Alseodaphne petiolaris</i> Hook.f.	10	3.75	0.32	2.69	C
<i>Anogeissus acuminata</i> (Roxb.ex DC) Guill.	5	2.5	0.44	2.17	C
<i>Aphananthe cuspidata</i> (Blume) Planch	10	3.75	0.23	2.47	C
<i>Aporosa octandra</i> (Buch.-Ham.ex D.Don) Vickery	15	6.25	0.13	3.33	C

<i>Baccaurea ramiflora</i> Lour.	10	2.5	0.05	1.72	C
<i>Balakata baccata</i> (Roxb.) Esser	5	1.25	0.02	0.85	C
<i>Bombax insigne</i> Wall.	10	3.75	0.17	2.34	C
<i>Calliandra umbrosa</i> (Wall.) Benth.	15	5	0.10	2.95	C
<i>Callicarpa arborea</i> Roxb.	5	5	0.36	2.59	C
<i>Canarium bengalense</i> Roxb.	5	1.25	0.27	1.46	C
<i>Canthium glabrum</i> Blume	5	1.25	0.01	0.83	C
<i>Castanopsis tribuloides</i> (Sm.) A.D.C.	15	12.5	1.04	7.10	C
<i>Cephalotaxus griffithii</i> Hook.f	5	6.25	0.59	3.46	C
<i>Chisocheton cumingianus</i> (C.D.C.) Harms	5	3.75	1.11	4.13	C
<i>Chukrasia tabularis</i> A.Juss	10	2.5	0.55	2.94	C
<i>Cinnamomum cassia</i> (L.) J.Presl	10	2.5	0.03	1.68	C
<i>Cinnamomum tamala</i> (Buch.-Ham.) T. Nees & Eberm.	10	2.5	0.21	2.13	C
<i>Cordia fragrantissima</i> Kurz.	5	1.25	0.01	0.82	C
<i>Dimocarpus longan</i> Lour.	5	1.25	0.14	1.14	C
<i>Diospyros malabarica</i> (Desr.) Kostel	5	2.5	0.03	1.18	C
<i>Diospyros pilosiuscula</i> G.Don	15	5	0.28	3.41	C
<i>Diospyros racemosa</i> Roxb.	20	6.25	0.28	4.20	C

<i>Diospyros stricta</i> Roxb	5	1.25	0.11	1.06	C
<i>Dipterocarpus turbinatus</i> C.F.Gaertn.	5	6.25	2.28	7.59	C
<i>Dysoxylum mollissimum</i> (Blume) Miq.	5	1.25	0.02	0.86	C
<i>Elaeocarpus lanceifolius</i> Roxb.	5	1.25	0.04	0.90	C
<i>Engelhardtia spicata</i> Lesch. Ex Blume	10	3.75	0.37	2.81	C
<i>Erythrina stricta</i>	5	1.25	0.05	0.93	C
<i>Eurya cerasifolia</i> (D.Don) Kobuski	5	1.25	0.04	0.90	C
<i>Ficus glaberrima</i> Blume	5	2.5	0.22	1.63	C
<i>Ficus retusa</i> L.	10	3.75	1.15	4.73	C
<i>Firmiania colorata</i> (Roxb.) R.Br.	5	1.25	0.26	1.45	C
<i>Flacourtia jangomas</i> (Lour.) Raeusch	20	8.75	0.48	5.31	C
<i>Garcinia cowa</i> Roxb.ex Choisy	10	2.5	0.03	1.67	C
<i>Garcinia pedunculata</i> Roxb.ex Buch-Ham	15	5	0.07	2.88	C
<i>Gmelina arborea</i> Roxb.	10	3.75	0.47	3.05	C
<i>Gmelina oblongifolia</i>	5	1.25	0.07	0.98	C
<i>Gynocardia odorata</i> R.Br.	15	10	0.63	5.46	C
<i>Haldina cordifolia</i> (Roxb.)	15	5	0.32	3.50	C

<i>Heritiera papilio</i> Bedd.	5	1.25	1.01	3.27	C
<i>Hymenodictyon orixense</i> (Roxb.) Mabb.	5	1.25	0.02	0.85	C
<i>Ixora nigricans</i> R.Br. Ex Wight & Arn.	10	2.5	0.04	1.71	C
<i>Lannea coromandelica</i> (Houtt.) Merr.	5	3.75	0.12	1.71	C
<i>Ligustrum robustum</i> (Roxb.) Blume	5	1.25	0.01	0.83	C
<i>Lindera nacusua</i> (D.Don) Merr.	15	5	0.49	3.90	C
<i>Litsea monopetala</i> (Roxb.) Pers.	10	3.75	2.06	6.94	C
<i>Macaranga denticulata</i> (Blume) Mull.Arg.	5	2.5	0.77	3.00	C
<i>Macaranga indica</i> Wight	10	2.5	0.11	1.88	C
<i>Macropanax undulatus</i> (Wall. Ex. G.Don) Seem.	30	23.75	0.74	10.61	C
<i>Magnolia baillonii</i> Pierre	10	10	0.99	5.85	C
<i>Magnolia hodgsonii</i> (Hook.f & Thomson) H.Keng	5	1.25	0.03	0.87	C
<i>Magnolia oblonga</i> (Wall. Ex Hook.f. & thomson) Figlar	15	6.25	3.10	10.59	C
<i>Mesua ferrea</i> L.	40	21.25	1.29	12.33	C
<i>Mitragyna diversifolia</i> (Wall.ex G.Don) Havil.	10	2.5	0.14	1.96	C

<i>Myristica angustifolia</i> Roxb.	15	7.5	0.11	3.59	C
<i>Nyssa javanica</i> (Blume) Wangerin	20	7.5	0.50	5.04	C
<i>Phoebe hainesiana</i> Brandis	15	5	0.69	4.39	C
<i>Phyllanthus emblica</i> L.	5	1.25	0.07	0.99	C
<i>Polyalthia jenkinsii</i> (Hook.f. & Thomson) Hook.f. & Thomson	10	3.75	0.11	2.18	C
<i>Polyalthia simiarum</i> (Buch-Ham.ex Hook.f.&Thomson)Benth.&Hoof.f	10	2.5	0.04	1.71	C
<i>Protium serratum</i> (Wall.ex Colebr.) Engl.	5	1.25	0.19	1.26	C
<i>Prunus ceylanica</i> (Wight) Miq.	30	10	0.51	6.67	RA
<i>Pterospermum acerifolium</i> (L.) Willd.	5	1.25	0.28	1.50	C
<i>Pterygota alata</i> (Roxb.) R.Br.	5	1.25	0.11	1.07	C
<i>Sapindus mukorossi</i> Gaertn.	10	3.75	0.52	3.18	C
<i>Saraca asoca</i> (Roxb.) W.J. de Wilde	5	3.75	0.04	1.51	C
<i>Schima khasiana</i> Dyer	15	3.75	0.47	3.55	C
<i>Schima wallichii</i> (DC.) Korth.	60	25	2.38	17.90	RA
<i>Semecarpus anacardium</i> L.f.	10	3.75	0.21	2.44	C
<i>Spondias pinnata</i> (L.f.) Kurz	5	2.5	0.68	2.77	C
<i>Sterculia villosa</i> Roxb.	10	2.5	0.21	2.11	C
<i>Stereospermum chelonoides</i> (L.f.)	15	5	0.46	3.84	C

DC.					
<i>Syzygium claviflorum</i> (Roxb.)	30	12.5	0.31	6.80	C
<i>Syzygium cumini</i> (L.) Skeels	25	18.75	1.99	11.93	C
<i>Syzygium kurzii</i> (Duthei) N.P. Balakr.	10	3.75	0.05	2.03	C
<i>Tarennoidea wallichii</i> (Hook.f.) Tirveng. & Sastre	5	1.25	0.02	0.84	C
<i>Terminalia chebula</i> Retz.	5	2.5	0.16	1.50	C
<i>Terminalia citrina</i> (Roxb.ex Fleming)	20	7.5	0.51	5.06	C
<i>Terminalia crenulata</i> Roth.	10	5	3.15	9.89	C
<i>Terminalia myriocarpa</i> Van Heurck & Müll.Arg.	15	3.75	1.43	5.88	C
<i>Tetrameles nudiflora</i> R.Br.	10	2.5	0.30	2.34	C
<i>Toona ciliata</i> M.Roem.	10	3.75	0.44	2.99	C
<i>Walsura robusta</i> Roxb.	5	2.5	0.02	1.16	C

C- Clumped, RA – Random

Table 4.4.2 Family wise frequency, density, abundance, and FIVI recorded in the natural forest (core zone)

Family	Frequency (%)	Density (stem/ha)	BA (m²/ha)	FIVI
Achariaceae	15	10	0.63	5.67
Anacardiaceae	15	10	1.02	6.63
Annonaceae	25	10	0.34	6.12
Araliaceae	30	23.75	0.74	11.03
Bignoniaceae	15	5	0.46	4.05
Boraginaceae	5	1.25	0.01	0.89
Burseraceae	10	2.5	0.46	2.86
Calophyllaceae	40	21.25	1.29	12.90
Cannabaceae	10	3.75	0.23	2.61
Clusiaceae	20	7.5	0.10	4.34
Combretaceae	45	21.25	5.68	24.15
Dipterocarpaceae	5	6.25	2.28	7.66
Ebenaceae	30	15	0.70	8.78
Elaeocarpaceae	5	1.25	0.04	0.97
Euphorbiaceae	15	6.25	0.90	5.44
Fabaceae	40	17.5	0.72	10.57
Fagaceae	15	12.5	1.04	7.31
Juglandaceae	10	3.75	0.37	2.95
Lamiaceae	20	10	0.90	6.91
Lauraceae	50	25	3.83	21.14

Magnoliaceae	30	17.5	4.12	17.73
Malvaceae	40	11.25	2.05	12.30
Meliaceae	50	18.75	2.36	16.01
Moraceae	15	6.25	1.37	6.57
Myristicaceae	15	7.5	0.11	3.81
Myrtaceae	55	35	2.35	20.55
Nyssaceae	20	7.5	0.50	5.32
Oleaceae	5	1.25	0.01	0.90
Pentaphylacaceae	5	1.25	0.04	0.97
Phyllanthaceae	30	10	0.25	6.45
Rosaceae	30	10	0.51	7.10
Rubiaceae	35	13.75	0.56	8.70
Rutaceae	5	1.25	0.03	0.95
Salicaceae	20	8.75	0.48	5.59
Sapindaceae	15	5	0.66	4.53
Simaroubaceae	15	2.5	0.16	2.71
Taxaceae	5	6.25	0.59	3.53
Tetramelaceae	10	2.5	0.30	2.49
Theaceae	60	28.75	2.85	20.80

The secondary forest in the buffer zone exhibited lesser species diversity, represented by 67 tree species across 36 families. *Gmelina arborea* with 30 individuals emerged as the most abundant species, followed by *Schima wallichii* represented by 21 individuals, *Macaranga indica* (13), *Sterculia villosa* (10), and *Mangifera indica* with 10 individual stands. The top 5 highest IVI values were recorded for *Gmelina arborea* (32.19), followed by *Schima wallichii* (20.22), *Macaranga indica* (16.25), *Callicarpa arborea* (16.22), and *Sterculia villosa* (15.58)

(Table 4.4.3), reflecting their ecological dominance. Family-wise dominance analysis revealed that Lamiaceae with an FIVI value of 55.07 was the most dominant family, followed by Fabaceae (23.39), Malvaceae (22), and Theaceae (21.69) (Table 4.4.4).

Table 4.4.3 Phytosociological attributes of tree species in the secondary forest (buffer zone)

Species	Frequency (%)	Density (stem/ha)	BA (m ² /ha)	IVI	A/F
<i>Adenanthera pavonina</i> L.	5	1.25	0.01	1.22	C
<i>Aglaia spectabilis</i> (Miq.)S.S.Jain&S.Bennet	25	11.25	0.94	13.78	C
<i>Ailanthus integrifolia</i> Lam.	10	5	0.27	4.94	C
<i>Alangium chinense</i> (Laur.) Harms	10	2.5	0.06	2.77	C
<i>Albizia procera</i> (Roxb.)Benth.	15	3.75	0.09	4.12	C
<i>Aporosa octandra</i> (Buch.-Hamex D.Don)Vickery	15	5	0.39	6.50	C
<i>Ardisia polycephala</i> Wall.ex A.D.C.	5	1.25	0.10	1.84	C
<i>Artocarpus lakoocha</i> Roxb.	10	2.5	0.03	2.51	C
<i>Artocarpus heterophyllus</i> Lam.	15	8.75	0.14	6.12	C
<i>Baccaurea ramiflora</i> Lour.	10	2.5	0.05	2.71	C
<i>Balakata baccata</i> (Roxb.) Esser	10	3.75	0.17	3.88	C
<i>Bischofia javanica</i> Blume	5	1.25	0.01	1.27	C
<i>Bombax insigne</i> Wall.	5	2.5	0.15	2.59	C
<i>Callicarpa arborea</i> Roxb.	35	17.5	0.71	15.84	C

<i>Cassia javanica</i> L.	5	1.25	0.25	2.88	C
<i>Castanopsis lanceifolia</i> (Oerst.) Hickel&A.Camus	10	3.75	0.07	3.22	C
<i>Castanopsis tribuloides</i> (Sm.) A.D.C.	10	5	0.17	4.29	C
<i>Cephalotaxus griffithii</i> Hook.f.	5	1.25	0.17	2.29	C
<i>Cinnamomum bejolghota</i> (Buch.- Ham.)Sweet	5	1.25	0.01	1.26	C
<i>Cordia dichotoma</i> G.Forst.	5	1.25	0.04	1.40	C
<i>Derris robusta</i> (Roxb.ex DC.) Bent.	10	8.75	0.27	6.19	C
<i>Diospyros pilosiuscula</i> G.Don	5	1.25	0.10	1.85	C
<i>Duabanga grandiflora</i> (Rxb.ex DC.) Walp.	5	1.25	0.09	1.77	C
<i>Elaeocarpus lanceifolius</i> Roxb.	5	1.25	0.18	2.40	C
<i>Erythrina stricta</i> Roxb.	5	1.25	0.08	1.69	C
<i>Ficus fistulosa</i> Reinw.ex Blume	10	3.75	0.14	3.72	C
<i>Ficus glaberrima</i> Blume	5	1.25	0.02	1.32	C
<i>Ficus prostrate</i> (Wall.ex.Miq.) Buch.-Ham.exMiq.	10	1.25	0.01	2.01	RA
<i>Ficus racemosa</i> L.	5	1.25	0.01	1.26	C
<i>Garuga floribunda</i> Decne.	5	1.25	0.06	1.59	C
<i>Gmelina arborea</i> Roxb.	20	37.5	2.48	31.9 7	C
<i>Haldinia cordifolia</i> (Roxb.)Ridsdale	5	1.25	0.10	1.86	C
<i>Heteropanax fragrans</i> (Roxb.) Seem.	20	5	0.16	5.75	RA

<i>Hibiscus macrophyllus</i> Roxb.ex Hornem.	15	3.75	0.09	4.12	C
<i>Hydnocarpus kurzii</i> (King)Warb.	15	6.25	0.32	6.50	C
<i>Ixora nigricans</i> R.Br.ex Wight&Arn.	5	1.25	0.04	1.45	C
<i>Laurocerasus undulate</i> (Buch.-Ham.ex D.Don) M.Roem.	5	1.25	0.02	1.30	C
<i>Ligustrum robustum</i> (Roxb.)Blume	5	1.25	0.08	1.70	C
<i>Litsea monopetala</i> (Roxb.) Pers.	25	11.25	0.54	11.1 2	C
<i>Macaranga indica</i> Wight	35	16.25	0.78	15.8 6	C
<i>Magifera indica</i> L.	15	12.5	0.52	9.89	C
<i>Magnolia oblonga</i> (Wall.exHook.f.&Thompson)Figlar	5	1.25	0.07	1.64	C
<i>Mesua ferrea</i> L.	20	5	0.24	6.31	RA
<i>Miliusa roxburghiana</i> Wall.ex Hook.f.&Thompson	5	1.25	0.01	1.26	C
<i>Myristica angustifolia</i> Wall.	5	1.25	0.04	1.42	C
<i>Oreocnide integrifolia</i> (Gaudich.) Miq.	5	1.25	0.02	1.27	C
<i>Oroxylum indicum</i> (L.) Kurz	5	1.25	0.01	1.26	C
<i>Ostodes paniculata</i> Blume	10	5	0.14	4.08	C
<i>Parkia timoriana</i> (DC.) Merr.	15	7.5	0.17	5.88	C
<i>Phoebe hainesiana</i> Brandis	5	1.25	0.18	2.39	C
<i>Prunus ceylanica</i> (Wigth) Miq.	10	5	0.20	4.50	C

<i>Saraca asoca</i> (Roxb.)Willd.	5	2.5	0.04	1.84	C
<i>Saurauia punduana</i> Wall.	10	5	0.06	3.59	C
<i>Schima wallichii</i> (DC.)Korth.	30	26.25	1.12	20.7 0	C
<i>Semecarpus anacardium</i> L.f.	5	1.25	0.01	1.23	C
<i>Sterculia villosa</i> Roxb.ex DC.	15	12.5	1.35	15.4 2	C
<i>Stereospermum chelonoides</i> (L.f.) DC.	5	1.25	0.21	2.55	C
<i>Sterospermum tetragonum</i> DC.	5	1.25	0.31	3.26	C
<i>Syzygium cumini</i> (L.)Skeels	5	2.5	0.22	3.05	C
<i>Tectona grandis</i> L.f.	5	5	0.10	3.07	C
<i>Terannoidea wallichii</i> (Hook.f.&Thomsom) Pichon	5	1.25	0.07	1.66	C
<i>Terminalia chebula</i> Retz.	5	1.25	0.04	1.43	C
<i>Tetrameles nudiflora</i> R.Br.	5	1.25	0.04	1.44	C
<i>Toona ciliata</i> M.Roem.	15	3.75	0.08	4.01	C
<i>Trema orientalis</i> (L.) Blume	5	1.25	0.12	1.95	C
<i>Vitex peduncularis</i> Wall.ex Schauer	5	2.5	0.05	1.94	C
<i>Vitex quinata</i> (Lour.) F.N.Williams	5	1.25	0.15	2.14	C

C- Clumped, RA - Random

Table 4.4.4 Family wise frequency, density, abundance, and FIVI recorded in the secondary forest (buffer zone)

Family	Frequency (%)	Density (stem/ha)	BA (m²/ha)	FIVI
Achariaceae	15	6.25	0.32	6.59
Actinidiaceae	10	5	0.06	3.64
Anacardiaceae	20	13.75	0.53	11.25
Annonaceae	5	1.25	0.01	1.29
Apocynaceae	5	1.25	0.07	1.69
Araliaceae	20	5	0.16	5.86
Bignoniaceae	15	3.75	0.53	7.17
Boraginaceae	5	1.25	0.03	1.43
Burseraceae	5	1.25	0.06	1.62
Calophyllaceae	20	5	0.24	6.42
Cannabaceae	5	1.25	0.11	1.96
Cephalotaxaceae	5	1.25	0.17	2.32
Combretaceae	5	1.25	0.04	1.46
Cornaceae	10	2.5	0.06	2.82
Ebenaceae	5	1.25	0.11	1.92
Elaeocarpaceae	5	1.25	0.18	2.44
Euphorbiaceae	45	25	1.06	22.46
Fabaceae	55	26.25	0.91	23.39
Fagaceae	20	8.75	0.24	7.62
Lamiaceae	70	63.75	3.42	55.07
Lauraceae	35	13.75	0.73	14.96
Lythraceae	5	1.25	0.09	1.8
Magnoliaceae	5	1.25	0.07	1.67

Malvaceae	35	18.75	1.53	22
Meliaceae	40	15	1.01	18.04
Moraceae	45	18.75	0.36	15.65
Myristicaceae	5	1.25	0.04	1.45
Myrtaceae	10	2.5	0.22	3.87
Oleaceae	5	1.25	0.08	1.73
Phyllanthaceae	25	8.75	0.45	9.87
Primulaceae	5	1.25	0.1	1.87
Rosaceae	15	6.25	0.22	5.89
Rubiaceae	10	2.5	0.15	3.37
Simaroubaceae	10	5	0.27	5.01
Tetramelaceae	5	1.25	0.04	1.47
Theaceae	35	26.25	1.12	21.68
Urticaceae	5	1.25	0.01	1.29

A total of 10 tree species are recorded from the current jhum site, *Schima wallichii* (IVI= 67.77) and *Albizia procera* (IVI= 53.85) emerged as the most dominant trees in this site (Table 4.4.5).

Table 4.4.5 Phytosociological attributes of tree species in the current jhum (buffer zone)

Species	Frequency	Density (stem/ha)	BA (m ² /ha)	IVI	A/F
<i>Albizia procera</i> (Roxb.) Benth	33.33	0.3	10	53.85	RA
<i>Balakata baccata</i> (Roxb.) Esser	6.67	0.15	1.67	14.67	C
<i>Bischofia javanica</i> Blume	13.33	0.05	3.33	16.77	C
<i>Callicarpa arborea</i> Roxb.	13.33	0.1	5	22.41	C
<i>Gmelina arborea</i> Roxb.	40	0.48	15	76.46	RA
<i>Hibiscus macrophyllus</i> Roxb. Ex Hornem	6.67	0.07	1.67	10.4	C
<i>Litsea monopetala</i> (Roxb.) Pers.	6.67	0.08	1.67	11.32	C
<i>Macaranga indica</i> Wight	13.33	0.05	3.33	16.77	C
<i>Schima wallichii</i> (DC.) Korth.	26.67	0.64	10	67.11	C
<i>Toona ciliate</i> M.Roem.	6.67	0.07	1.67	10.4	C

The oil palm (*Elaeis guineensis*) plantation site exhibited a total of 7 species with *Elaeis guineensis* recorded as the most dominant species, followed by *Magnolia champaca* and *Albizia procera* (Table 4.4.6)

Table 4.4.6 Phytosociological attributes of tree species in the oil palm plantation (buffer zone)

Species	Frequency	Density (stem/ha)	IVI	A/F
<i>Ailanthus integrifolia</i> Lam.	5	1.25	11.02	C
<i>Albizia procera</i> (Roxb.) Benth.	5	2.5	18.33	C
<i>Artocarpus heterophyllus</i> Lam.	5	1.25	11.02	C
<i>Elaeis guineensis</i> Jacq.	100	197.5	222.27	C
<i>Gmelina arborea</i> Roxb.	5	1.25	11.02	C
<i>Magnolia champaca</i> (L.) Baill. Ex Pierre	10	2.5	15.32	C
<i>Schima wallichii</i> (DC.) Korth.	5	1.25	11.02	C

A total of 7 tree species are recorded from teak plantation site, with obvious dominance by *Tectona grandis*, while the species with the second highest IVI was *Mangifera indica* (Table 4.4.7)

Table 4.4.7 Phytosociological attributes of tree species in the teak plantation (buffer zone)

Species	Frequency	Density (stem/ha)	BA (m ² /ha)	IVI	A/F
<i>Artocarpus lakoocha</i> Buch-Ham.	6.67	3.33	0.07	5.35	C
<i>Gmelina arborea</i> Roxb.	6.67	3.33	0.05	5.29	C
<i>Litsea monopetala</i> (Roxb.) Pers.	6.67	1.67	0.02	4.88	C
<i>Mangifera indica</i> L.	13.33	5	0.12	10.36	C
<i>Spondias pinnata</i> (L.f.) Kurz	6.67	1.67	0.03	4.95	C
<i>Syzygium cumini</i> L.) Skeels	6.67	1.67	0.03	4.95	C
<i>Tectona grandis</i> L.f.	100	588.33	26.05	264.22	C

Areca nut based plantation recorded 9 tree species; the highest IVI value was exhibited by *Areca catechu* (254.47), followed by *Parkia timoriana* (IVI= 11.43) and *Gmelina arborea* (IVI = 8.06) (Table 4.4.8).

Table 4.4.8 Phytosociological attributes of tree species in the areca nut plantation (buffer zone)

Species	Frequency	Density (stem/ha)	BA (m ² /ha)	IVI	A/F
<i>Areca catechu</i> L.	100	1065	14.46	254.47	C
<i>Artocarpus heterophyllus</i> Lam.	10	2.5	0.05	6.79	C
<i>Citrus reticulata</i> Blanco	5	2.5	0.08	3.88	C
<i>Gmelina arborea</i> Roxb.	10	3.75	0.23	8.06	C
<i>Hibiscus macrophyllus</i> Roxb. Ex Hornem	5	1.25	0.05	3.56	C
<i>Magnolia champaca</i> (L.) Baill,ex Pierre	5	1.25	0.05	3.56	C
<i>Mangifera indica</i> L.	5	3.75	0.19	4.69	C
<i>Parkia timoriana</i> (DC.) Merr.	15	5	0.24	11.43	C
<i>Toona ciliata</i> M.Roem.	5	1.25	0.05	3.57	C

Community parameters

The different land use systems showed marked differences in their community attributes. The natural forest in the core zone of the reserve exhibited the highest diversity and evenness index, followed by the secondary forest, current jhum, oil palm, teak and areca nut plantation (Table 4.4.9). In contrast, dominance index exhibited an opposite trend, with highest value in the areca nut and lowest in the natural forest. Stand density was also highest in the areca nut plantation site and lowest in the current jhum.

Table 4.4.9 Summary of vegetation parameters in the different land use systems

Parameters	Natural forest	Secondary forest	Teak	Areca nut	Oil palm	Current jhum
Shannon-Weiner Diversity Index	4.15	3.64	0.17	0.13	0.27	1.19
Simpson Dominance Index	0.02	0.04	0.94	0.96	0.90	0.14
Pielou's Evenness Index	0.92	0.87	0.08	0.07	0.13	0.86
Stand Density (ind./ha)	409	303	605	1086	208	54
Basal Cover (m ² /ha)	51.28	19	26.27	15.39	–	1.99

Dominance Distribution

The dominance distribution curves of tree species in the natural and secondary forests yielded a log-normal distribution pattern, reflecting stability, and evenness of the community. Whereas, the dominance distribution curves of the oil palm, teak and areca nut plantations yielded a geometric curve signifying strong dominance by few species, reflecting low evenness (Figure 4.4.1).

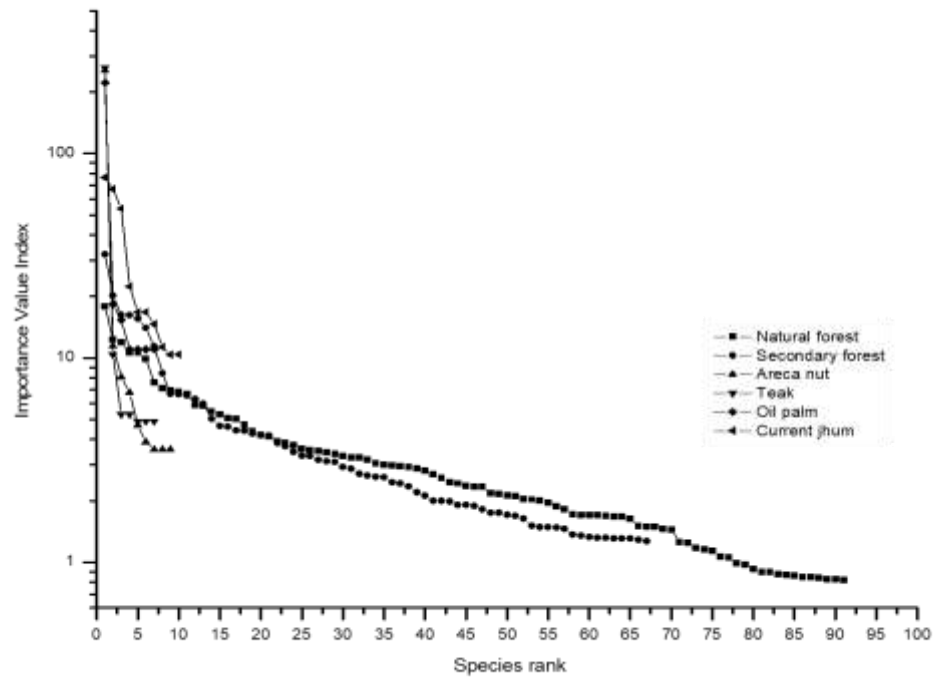


Figure 4.4.1 Dominance curve of recorded tree species in selected land use systems

Sorensen's similarity index

Sorensen similarity of tree species composition varied markedly among the six land-use systems (Figure 4.4.2). Similarity between natural forest and secondary forest was moderate (39%), whereas natural forest shared relatively few species with current jhum, oil palm, teak and areca nut systems (13%, 6%, 10%, and 6%, respectively). Current jhum showed the highest similarity with oil palm plantations (35%), and intermediate similarity with areca nut (32%) and teak (24%). Oil palm and teak, and teak and areca nut, also exhibited low to moderate similarity.

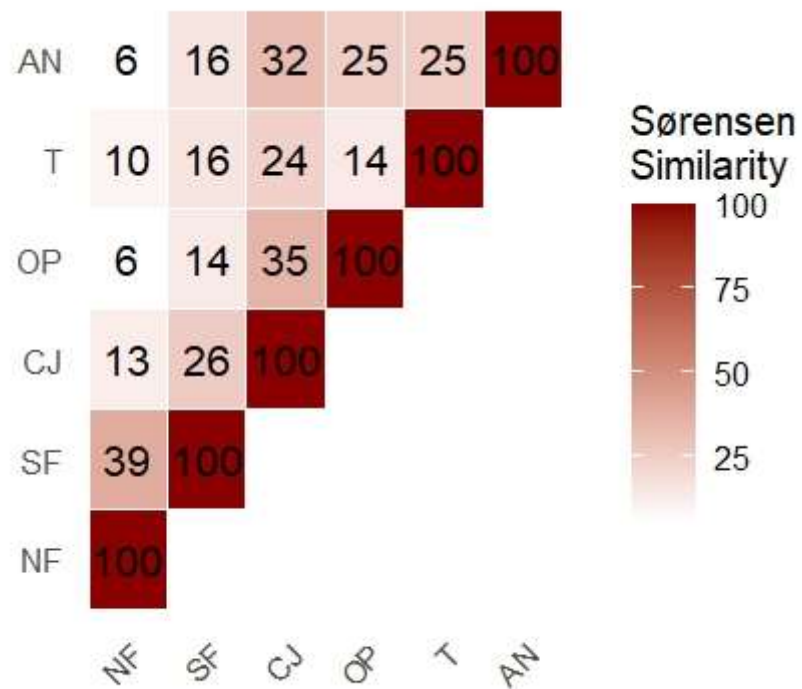


Figure 4.4.2 Sorensen's Similarity Index: Pairwise comparison of species composition similarity

Linear regression analysis of the forest structural and diversity attributes of the natural and secondary forests

Basal area and species richness: The linear regression analysis between the basal area and species richness showed a significant but weak relationship, indicating that with an increase in richness level, the basal area also increases in the DTR forest (Figure 4.4.3).

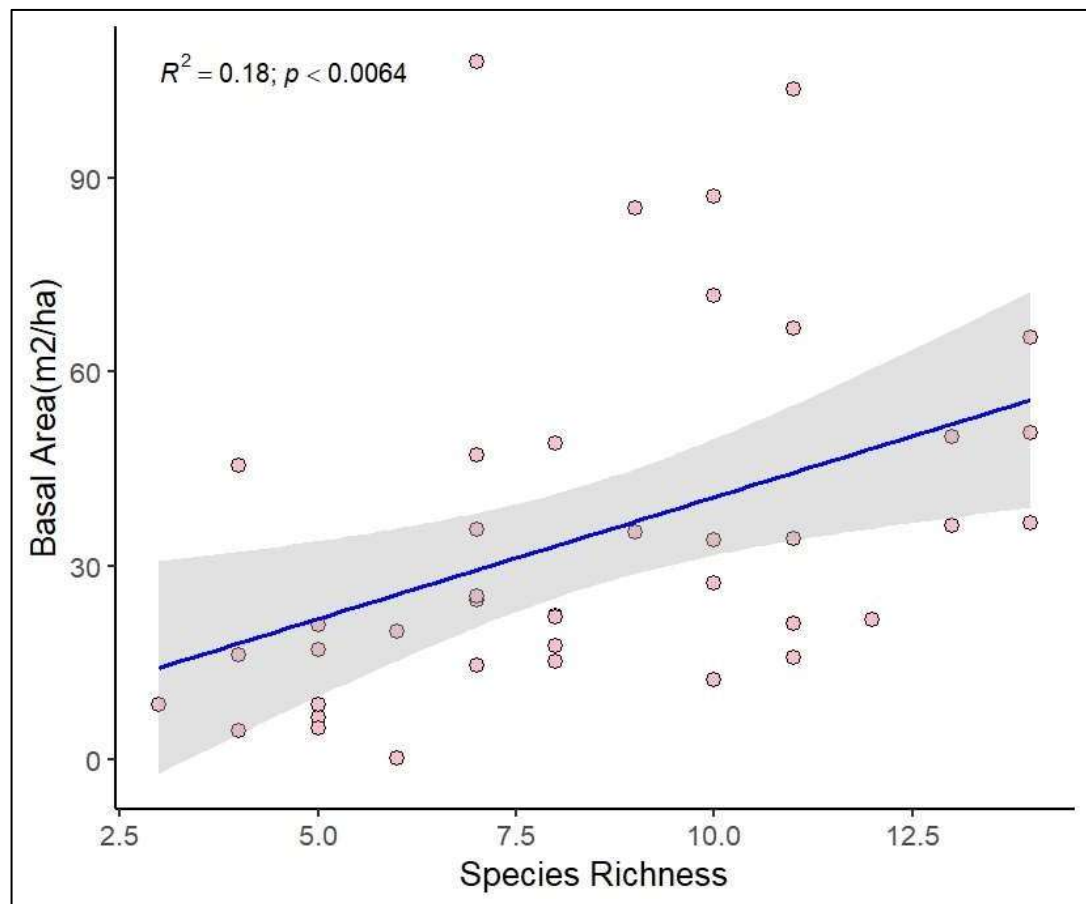


Figure 4.4.3 Linear regression showing the relationship between species richness and basal area in DTR forest

Basal area and tree density: A weak significant relationship was observed between the basal area and tree density according to the linear regression analysis, indicating that the more the number of individuals, the basal area also increases (Figure 4.4.4)

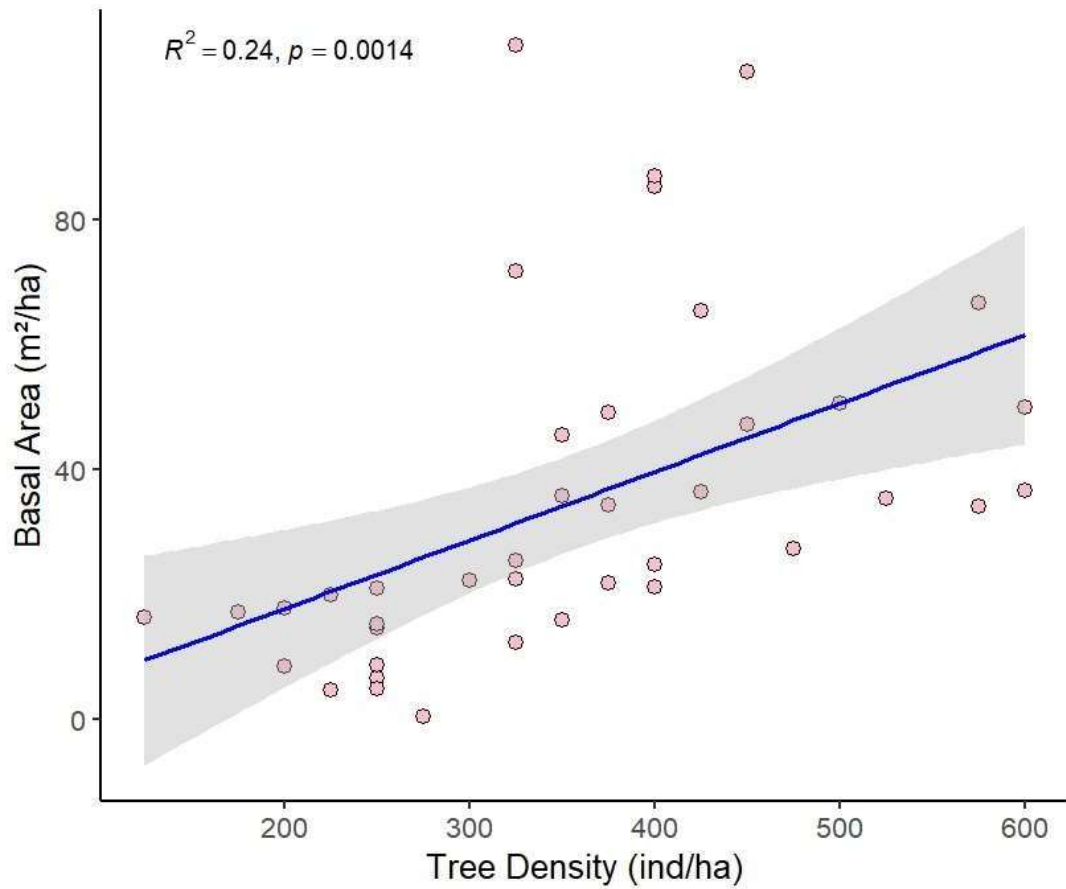


Figure 4.4.4 Linear regression showing the relationship between tree density and basal area in DTR forest

Species Richness and Tree Density: The linear regression analysis showed that tree density and species richness exhibited a moderate significant relationship, with tree density explaining 57% of variations in species richness (Figure 4.4.5).

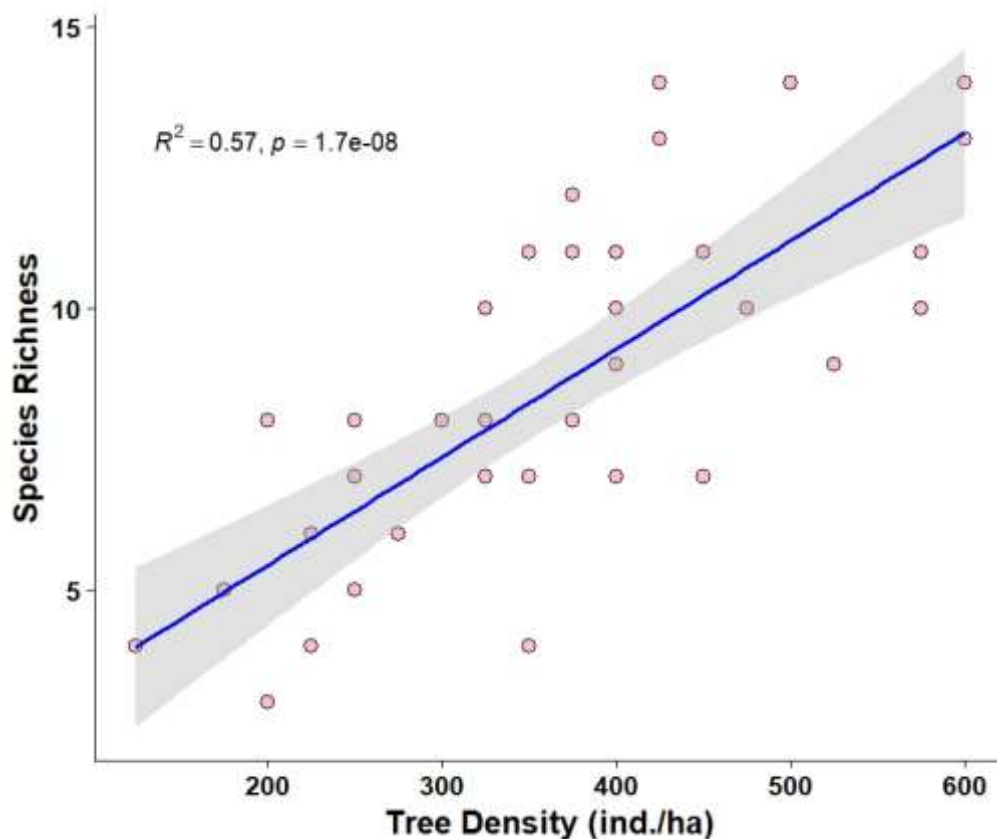


Figure 4.4.5 Linear regression showing the relationship between tree density and species richness in DTR forest

Girth class distribution in natural forest and secondary forest

The girth class distribution was extended upto >330 cm in the natural forest within the core zone, whereas it was restricted upto 211–240 cm in the secondary forest within the buffer zone (Figure 4.4.6. and 4.4.7.). In the natural forest, the smallest girth class (30–60 cm) accounted for the highest stand abundance, while the 300–330 cm girth class accounted for the lowest abundance. The >330 girth class contributed to the maximum basal area and the minimum value was reported from the 300-330 girth class. In the secondary forest, the tree abundance pattern followed a decreasing order from the smallest to the biggest girth class. The 91–120 cm girth class accounted for the maximum basal area, while the 211-240 cm girth class exhibited the minimum basal area.

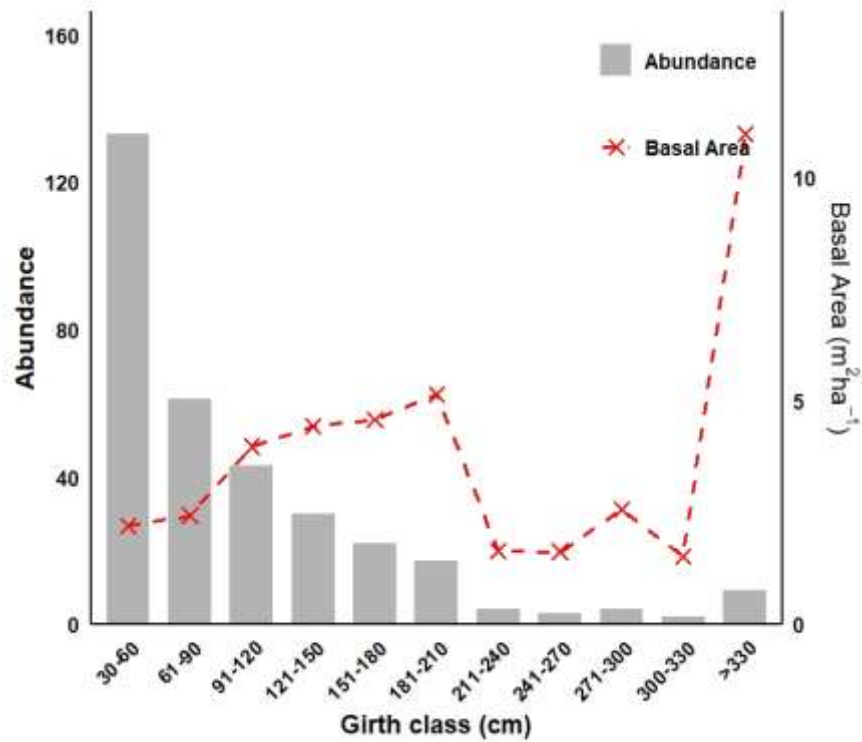


Figure 4.4.6 Distribution of individuals and basal area in the different girth class in the natural forest within the core zone

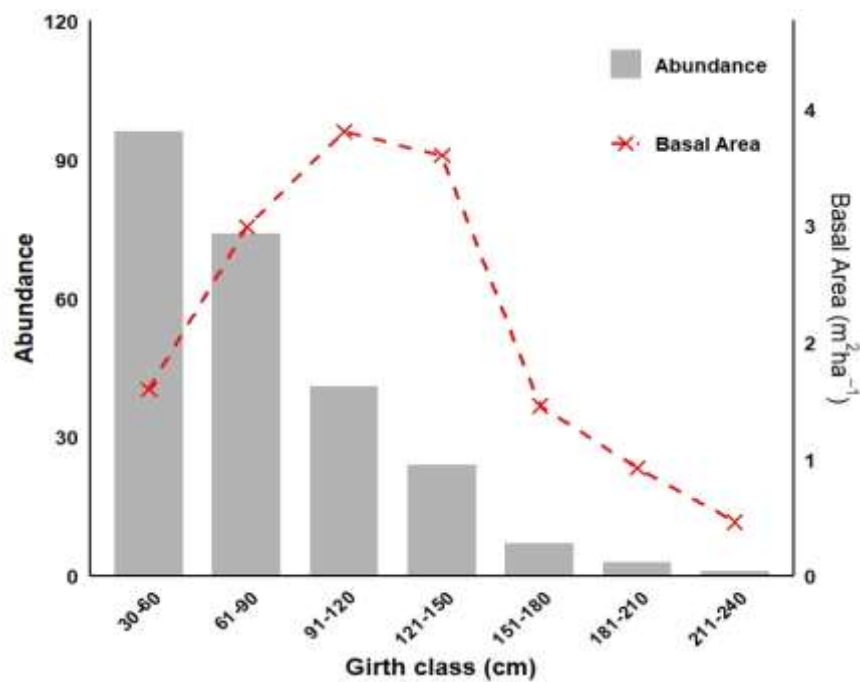


Figure 4.4.7 Distribution of individuals and basal area in the different girth class in the secondary forest within the buffer zone.

Prediction of trees and species absence in the buffer zone

The probability of natural forest's trees absence in the secondary forest within the buffer zone was modeled using a multiple logistic regression analysis. The results revealed that the probability of trees absence was increased with an increase in DBH, suggesting that trees with large DBH are less likely to be found in the buffer zone. In contrast, red-listed status and high density reduced the chance of a tree being absent in the buffer zone (Table 4.4.10).

Table 4.4.10 Multiple Logistic regression model predicting tree absence in the buffer zone

Predictor variable	Parameter estimate	Standard errors	p(z test)	Odds ratios	95%Confidence Intervals	Type of variable
Red-listed	-1.612680	0.404646	-3.985	0.20	0.09-0.44	0/1
Dbh	0.025008	0.009117	2.743	1.03	1.01-1.05	Continuous
Density(n/ha)	-0.097093	0.017108	-5.675	0.91	0.88-0.94	Continuous
AIC	289.05					

Similarly, the probability of species absence was assessed using multiple logistic regression model (Table 4.4.11). Among the predictor variables, density alone was revealed to be marginally significant; hence, it was transformed using inverse and inverse power. Model comparison showed that the $(1/\text{density of species})^{0.25}$, with the lowest AIC value was the best fit model. Therefore, according to the logistic regression model, low stand density decrease the probability of species absence in the buffer zone.

Table 4.4.11 Logistic regression model predicting species absence in the secondary forest

Predictor variable	Model	p(z test)	AIC value
1/density of species	$\text{logit}(p) = -0.4232 + 1.9811 \times (1/\text{density})$	2.177	122.52
$(1/\text{density of species})^{0.25}$	$\text{logit}(p) = -2.488 + 3.744 \times (1/\text{density})^{0.25}$	2.248	122.25
Density(n/ha)	—	—	—
Red-listed	—	—	—
Dbh	—	—	—
NTFP	—	—	—

4.5. Drivers of Human-wildlife conflict and attitudes and perceptions of the local community

Household characteristics

Among all the 830 respondents, the largest proportion belonged to the 18–40 age group, and the mean age of the interviewees was 45 years. Then male population made up a large majority of the respondents in each sampled village (Table 4.5.1).

Table 4.5.1 Table showing household characteristics of 830 surveyed households around DTR (values are expressed as percentages)

Characteristics	Sub-characteristics	Damparengpui	Tuipuibari	West Phaileng	Phuldungsei	Total
Age	18–40	60.75	91	21.43	60.92	46.27
	41–60	32.71	82	48.5	27.01	39.52
	61–90	6.54	3	30.08	12.07	14.22
Gender	Male	59.5	84.7	88	67.8	75.78
	Female	40	15.3	12	32.2	24.22
Community	Bru	83.18	99.43	1.5	0	43.01
	Mizo	15.42	0.57	97.74	100	56.39
	Gorkhali	0.47	0	0	0	0.36
	Chakma	0.93	0	0.38	0	0.12
	Others	0	0	0.38	0	0.12
Education	No formal education	21.96	30.68	1.88	1.15	13.08
	Primary	21.03	25	19.17	16.67	20.36
	Middle	32.24	21.02	26.69	21.84	26.02
	High	21.03	17.05	33.08	43.68	28.8
	College	2.8	2.27	17.29	12.64	9.52
	Post–Graduation	0	3.98	1.88	4.02	2.29
Occupation	Farmer	50	47.16	8.65	17.82	29.83

	Govt. employee	4.67	3.98	32.71	7.47	14.3
	Daily wage	23.36	43.75	34.59	63.79	41.2
	Livestock	4.67	0	0.75	1.15	1.71
	Business	10.75	5.11	11.65	9.2	9.9
	Unemployed	1.87	0	4.51	0.57	2.08
	Others	3.27	0	7.14	0	1.71
Farm	Yes	62.62	48.86	45.86	86.21	59.37
	No	37.38	51.14	54.14	13.79	40.63
Type of Farm	Shifting	72.79	47.06	23.77	14.67	39.55
	Permanent	27.21	52.94	76.23	85.33	60.45

Areca nut, oil palm, orange, and banana were the major crops grown in permanent cultivation sites, either alone or in combination with other crops. However, jhum cultivation sites commonly featured rice, maize, taro, perilla, chilli, legumes, eggplant, bitter eggplant.

Nature of wildlife damage

34.22% of the total respondents claimed to have experienced problems with wildlife, mainly in the form of crop loss (70.57%), livestock depredation (8.11%), human casualties (15.32%) and property damage (6.01%).

Crop damage

Wildlife induced crop damage showed clear seasonal and temporal variations influenced by specific animal species and crop types. Most incidents occurred during the monsoon season and were concentrated during nocturnal hours. Wild boars and rodents were the primary crop raiding animals, while rice emerged as the most susceptible crop (Figure 4.5.1).

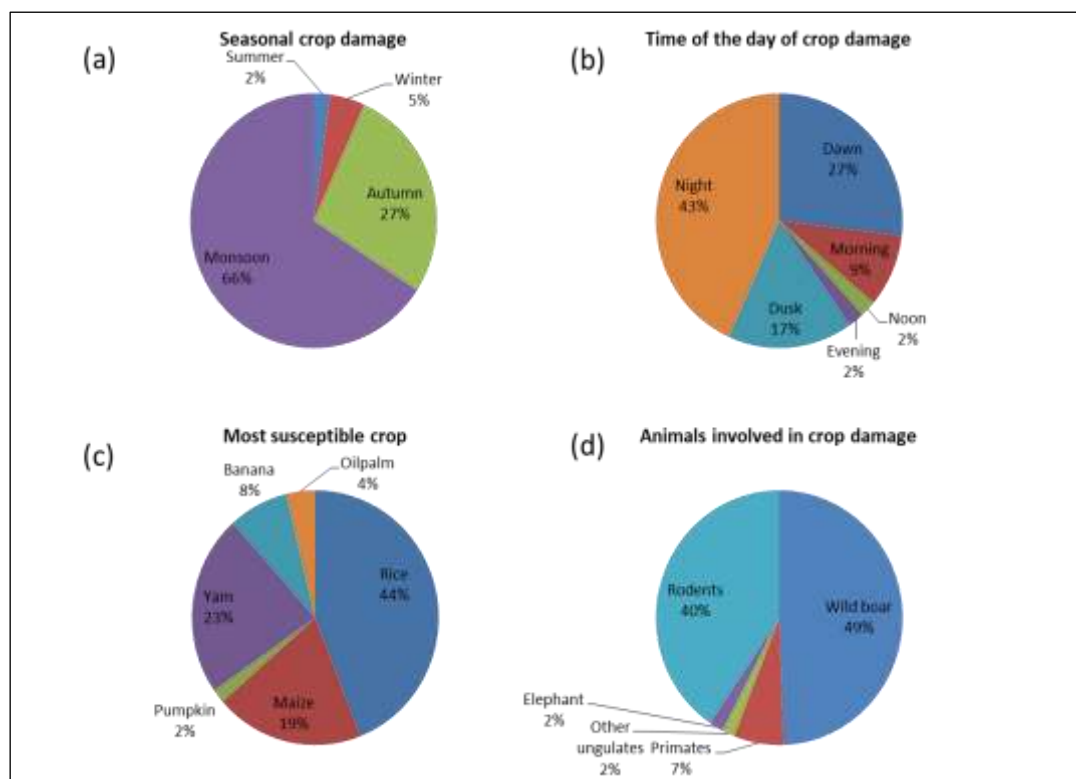


Figure 4.5.1 Patterns of crop damage in the study area showing (a) season of crop damage, (b) time of the day of crop damage, (c) most susceptible crop, and (d) animals involved in crop damage.

From the set of models explaining factors associated with self-reported household crop damage, two top models with $\Delta AICc < 2$ were selected. Crops that are typically grown in shifting cultivation systems such as rice and local vegetables were found to be strongly and positively associated with crop damage. Furthermore, the positive coefficients of crops such as bananas, oranges, pineapple, and oil palm suggested that households growing these crops were at higher risk of damage by wildlife. Interestingly, the use any guarding or mitigating measures were associated with increased crop loss, as evidenced by a positive beta coefficient (Table 4.5.2)

Table 4.5.2 Top models (Delta AICc <2) with estimated beta coefficients, SE, and p-value explaining factors influencing wildlife-induced crop damage in DTR.

Models	Crop Loss					
	Wi=0.71			Wi=0.27		
	Estimate	SE	P-value	Estimate	SE	P-value
Intercept	-3.36	0.935	<0.001	-3.374	0.397	<0.001
Distance_DTR	3.569×10^{-5}	1.093×10^{-5}	0.001	3.37×10^{-5}	1.16×10^{-5}	0.001
Areca nut & bananas	.227	0.54	<0.001	2.236	0.546	<0.001
Areca nut & oranges	1.137	1.396	0.415	1.06	1.428	0.458
Areca nut & pineapple	3.198	1.336	0.016	3.203	1.337	0.016
Bananas	3.052	0.601	<0.001	3.052	0.601	<0.001
Ginger	0.928	0.898	0.301	0.936	0.895	0.295
Oil palm	2.58	0.493	<0.001	2.585	0.493	<0.001
Oranges	1.174	0.519	0.023	1.165	0.52	0.025
Bitter beans	0.562	1.124	0.616	0.576	1.124	0.608
Rice & vegetables	4.308	0.405	<0.001	4.315	0.405	<0.001
Rubber	2.072	1.215	0.088	2.086	1.215	0.086
Sugarcane	3.522	0.742	<0.001	3.526	0.743	<0.001
Guarding(Yes)	1.368	0.287	<0.001	1.375	0.288	<0.001
Distance_WS	NA	NA	NA	2.18×10^{-5}	4.2×10^{-5}	0.61 0
Model AICc	401.463			403.351		
$\Delta AICc$	0			1.887		

Livestock Depredation

Figure 4.5.2 presents the distribution of domesticated animals reared by households within the study area.

Given the lower abundance of large carnivores in Dampa, smaller carnivores such as golden jackal and leopard cats were reported to be the only animals responsible for domestic animals depredation. The survey also revealed that chickens were the lone animals preyed upon by these carnivores, hence, the analysis also focused exclusively on them (Figure 4.5.3).

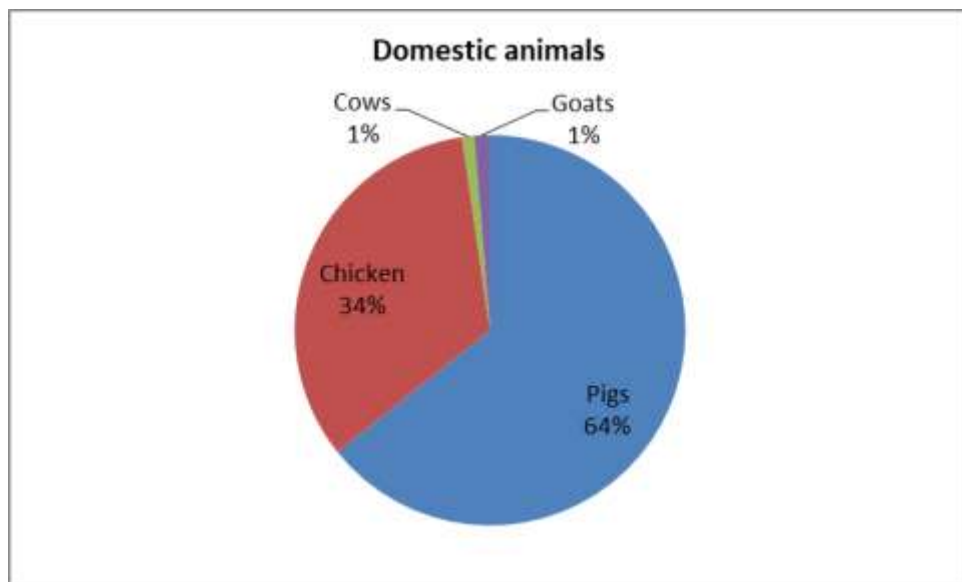


Figure 4.5.2 Proportion of major domesticated animal group

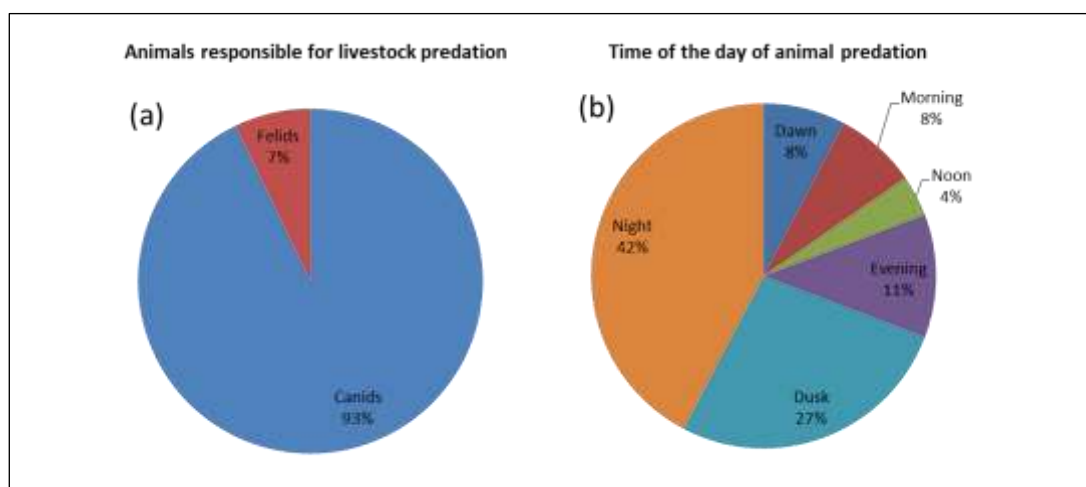


Figure 4.5.3 Pattern of livestock depredation showing (a) Animals involved in livestock depredation, and (b) time of the day of livestock depredation

Two models from the model set were selected as the best fit model based on their $\Delta AICc$. The top models explained that free ranging chickens were more susceptible to predation by wild animals as evidenced by the positive coefficient (Table 4.5.3). Predation on chickens occurred mostly during nocturnal hours with 42.31% of reported incidents occurring at night, and 26.92 % and 11.54% taking place in the dusk and evening hours.

Table 4.5.3 Top models (Delta AICc <2) with estimated beta coefficients, SE, and p-value explaining factors influencing livestock depredation in DTR.

Models	Livestock loss					
	Wi=0.57			Wi=0.277		
	Estimate	SE	p-value	Estimate	SE	p-value
Intercept	-3.588	0.413	<0.001	-3.392	0.454	<0.001
Free Ranging	5.785	1.132	<0.001	5.722	1.135	<0.001
Garden	4.504	0.636	<0.001	4.59	0.657	<0.001
Reason (Income)	NA	NA	NA	-0.556	0.64	0.385
Model AICc	92.947			94.232		
$\Delta AICc$	0			1.285		

Human casualties and property damage

6.14% of the total respondents claimed to have sustained injuries due to wild animals attack. Findings on human casualties revealed that snakes were responsible for the largest proportion of cases (Figure 4.5.4). Agriculture and forest-based activities emerged as activities that exposed individuals to greater risk of wild animal encounters.

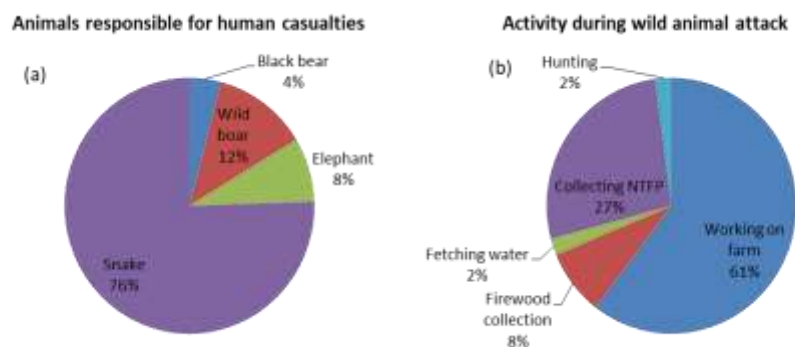


Figure 4.5.4 Pattern of human casualties showing (a) Animals responsible for human casualties (b) Activity during animal attack

Property damage by wild elephants specifically to farm huts and cooking utensils was reported exclusively from Damparengpui village by 2.41% of the total respondents.

Compensation access and people's perceptions

Only 35.21% of those experiencing wildlife related damages reported to the authorities and seek for financial compensation. The remaining 64.79 % cited the following reasons for not reporting: “never received even if applied” (39.86%), “didn’t feel the need to apply” (27.54%), “don’t know how to apply” (12.32%), “don’t know when to apply” (0.72%), and “amount is too less” (19.57%). 87.04% of recipients of financial compensation claimed that they were not satisfied with the amount received. From the model set, three top models were identified explaining factors driving households’ compensation claim. Village was associated with compensation claim, with people residing in West Phaileng village were more likely to report wildlife-related damages to the authorities and seek for financial compensation (Table 4.5.4)

Table 4.5.4 Top models (Delta AICc <2) with estimated beta coefficients, SE, and p-value explaining factors influencing compensation claim in DTR.

Models	W_i=0.33			W_i=0.20			W_i=0.12		
	Estimate	SE	p-value	Estimate	SE	p-value	Estimate	SE	p-value
Intercept	−0.860	0.262		−0.820	0.264	0.001	−0.549	0.962	0.568
Phuldungsei	−0.631	0.470	0.179	−0.666	0.471	0.166	−0.644	0.472	0.172
Tuipuibari	−0.807	0.538	0.133	−0.749	0.540	0.166	−0.802	0.538	0.136
West Phaileng	1.597	0.355	<0.001	1.613	0.357	<0.001	1.586	0.357	<0.001
CD	NA	NA	NA	NA	NA	NA	−0.319	0.944	0.735
PD	NA	NA	NA	NA	NA	NA	NA	NA	NA
Injury	NA	NA	NA	−0.568	0.540	0.293	NA	NA	NA
Loss	-1.18×10^{-5}	1.46×10^{-5}	0.41	-1.13×10^{-5}	1.45×10^{-5}	0.43	-1.16×10^{-5}	1.46×10^{-5}	0.428
Model AICc	280.189			281.125			282.178		
ΔAICc	0.000			0.935			1.987		

The multiple linear regression model identified factors influencing communities' perceptions towards wildlife conservation. Perception was found to improve significantly with higher levels of education, making education a key influencing factor. In addition, belonging to a particular village emerged an important factor shaping perception, with residents of Damparengpui village exhibiting a more positive perception towards wildlife conservation (Table 4.5.5).

Table 4.5.5 Multiple Linear Regression explaining socio-economic factors influencing people's perceptions towards wildlife conservation in DTR.

Model	Estimate	SE	p
Intercept	2.987	0.123	<0.001
Phuldungsei Village	-0.756	0.085	< 0.001
Tuipuibari Village	-0.299	0.050	<0.001
W.Phaileng Village	-0.713	0.080	< 0.001
Age	0.002	0.001	0.028
Gender (Male)	0.059	0.037	0.109
Community (Mizo)	0.234	0.076	0.002
Education	0.068	0.016	<0.001
Occupation (Business)	0.184	0.124	0.139
Occupation (Daily wage)	0.208	0.118	0.079
Occupation (Farmers)	0.223	0.122	0.067
Occupation (Govt.employee)	0.181	0.126	0.152
Occupation (Others)	0.321	0.144	0.025
Occupation (Unemployed)	0.029	0.156	0.851
Benefits (Yes)	0.051	0.048	0.294
Problem (Yes)	-0.058	0.038	0.130
Income	1.3×10^{-7}	1×10^{-7}	0.187

Occupation (Others) include drivers, carpenters, masons

Crop damage attributed to wildlife in the study area is presented in Figure 4.5.5. The most cited factor was the availability of readily accessible food resources in agricultural lands, accounting for 43% of total responses. Respondents stated that palatable food crops grown in the fields attract wild animals, leading to wildlife to forage in fields rather than their natural habitats.

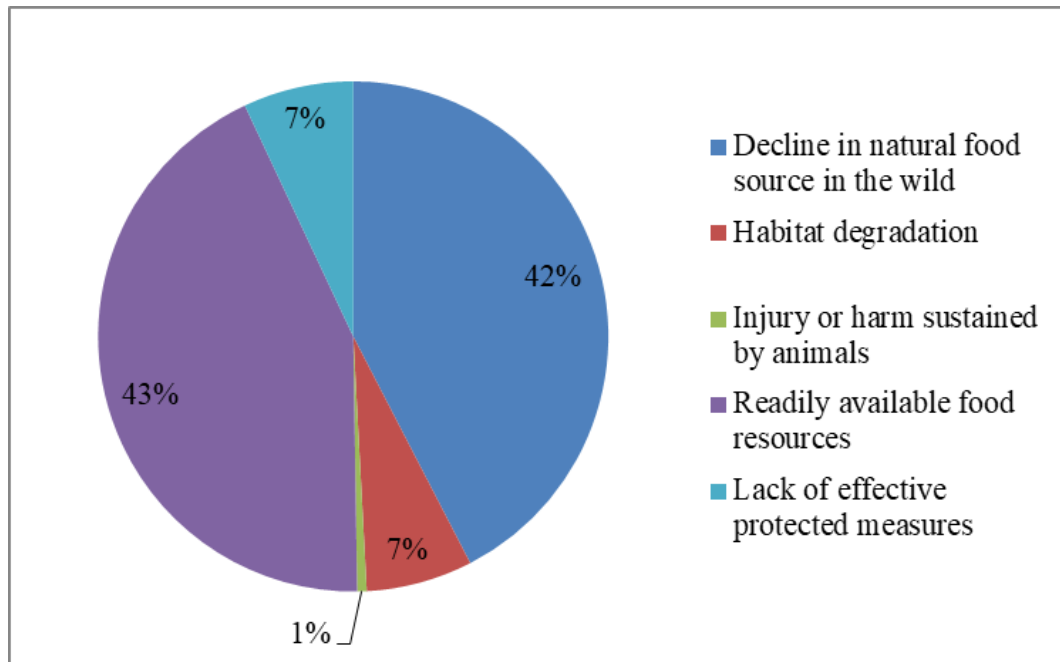


Figure 4.5.5 Perceived reasons for crop damage by wild animals

The decline in wild prey populations and the availability of easily accessible domestic animals were perceived as the major factors contributing to wildlife predation on livestock Figure 4.5.6

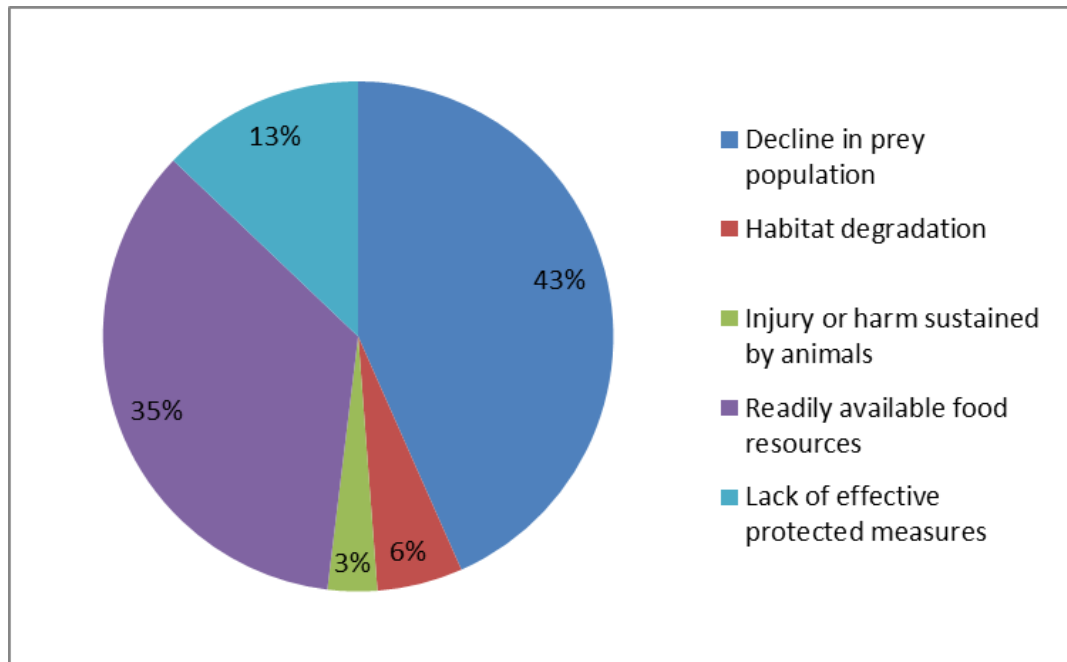


Figure 4.5.6 Perceived reasons for livestock predation by wild animals

Most respondents believed that wild animals seldom attack humans unless provoked or when injured, circumstances that may trigger defensive or aggressive responses. In contrast, a few respondents perceived that some animals are inherently aggressive by nature and therefore attack humans (Figure 4.5.7).

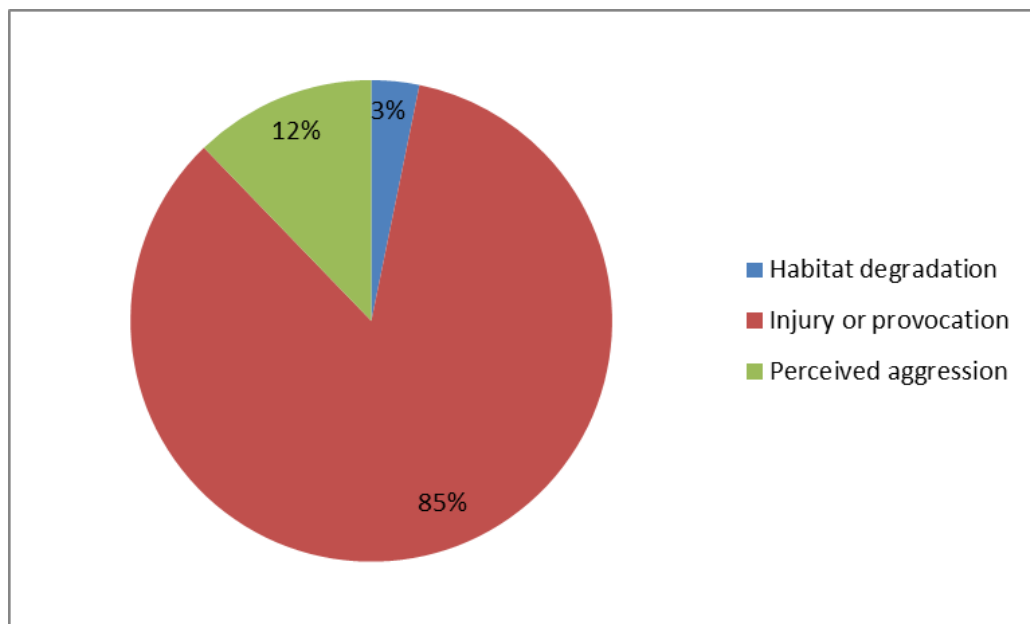


Figure 4.5.7 Perceived reasons for wild animals attack on human

Patterns and trends of land use/land cover change in DTR

The dominant land cover in DTR landscape in 2011 and 2021 was forest, which is mainly concentrated within the core zone of the reserve. This highlights the critical role and the effectiveness of notified protected areas like the core zone of DTR in sustaining forest cover and biodiversity amidst rapid land cover changes (Verburg et al., 2006). Deb et al. (2014) also reported that land use and land cover change within the Gumti Wildlife Sanctuary showed minimal change compared to the buffer zone of the PA. Similarly, in the Rio Abiseo National Park, Peru, significant land use changes were observed in the buffer zone, primarily involving the conversion of forest cover to agricultural land, while the core area of the park remained relatively stable and protected from such alterations (Kintz et al., 2006). In contrast, Wolf et al. (2023) documented significant land use change within the boundary of Jajrud Protected Area in Iran, which was mainly driven by the expansion in built-up areas, citing the lack of monitoring and ineffective management by relevant authorities as key factors contributing to these changes. Their findings emphasize the importance of effective management and consistent monitoring by concerned departments to prevent land use alterations and encroachment within protected areas.

Despite the minimal reduction in forest cover within DTR's core zone, the overall LULC demonstrated a declining trend in forest cover from 2011 to 2021. This reduction is primarily attributed to increased demand for land for agriculture, particularly, shifting cultivation and expansion of built-up areas, both of which continued to exert pressure on forest land. These land cover changes are closely linked to underlying socio-economic factors, population dynamics, and land use policies that influence how land is managed and utilized in the region. Consistent with the present study, findings from a study in Nambor wildlife sanctuary revealed significant land use transformation in the buffer zone, largely attributing to expansion of agricultural land (Kashyap et al., 2025). The confinement of

anthropogenic activities in the buffer zone owing to the legal protection status of the core area exerted immense pressure on land resource within this zone. The increasing human populations also exacerbated competition for scarce land resources, leading to intensified land use pressures and accelerated transformation of natural habitats within the buffer zone. Moreover, the cycle of jhum cultivation has reduced substantially driven by limited land resources and increasing population pressure has had significant impact on natural regeneration of forest, as reduced fallow period allows insufficient time for forests to recover fully between cropping cycles (Gouda et al., 2021). This growing demand for land coupled with limited access to resource use in the core zone amplified the exploitation of the buffer zone for agriculture, settlement expansion, and other human activities. The classified land use maps for both years indicate that anthropogenic land uses, such as shifting cultivation, settlements were intensified in the northwestern and northeastern, and southeastern part of the buffer zone. This could be attributed to the higher population densities in these areas. According to the 2011 census, West Phaileng and Damparengpui villages in the northeastern part had a population of 4377 and 2156, while Rajiv Nagar in the northwest and Silsuri in the southwest part of the area had a population of 3530 and 3347 respectively (Census of India, 2011).

Several land use policies have been implemented in the state of Mizoram with the aim of controlling or reducing the age old jhum cultivation. These include the Garden Colony Project, phase 1, 2, and 3 of the New Land Use Policy (NLUP), Jhum Control Project (JCP), the Mizoram Intodelh Project (MIP) (Thanga, 2020). While these interventions have demonstrated effectiveness in certain areas, including parts of the DTR landscape (Mandal & Raman, 2016); the findings of the present study revealed that areas under jhum cultivation have continued to increase. Besides jhum cultivation, plantations of teak, oil palm, areca nut, and rubber showed steady increase in the area. The LULC of 2021 indicated an expansion of built-up areas, which could be attributed to the population growth driven increase in settlement area and the construction of the Indo-Bangladesh border fence and patrol road stretching 62 km and several border outposts along the western boundary of the reserve. These infrastructures were primarily established to curb cross-border infiltration from the

neighboring Bangladesh. Given these factors, monitoring of land use and land cover dynamics is more critical than ever in the region.

Variation in microclimatic variables as affected by land use and seasons

The measured air temperature and relative humidity showed obvious land use and seasonal patterns, highlighting the significant impact of these factors on the microclimatic variables. Land use change directly alters the physical characteristics of the land surface like vegetation cover, leaf surface index, albedo, and heat flux, which are well-known to have significant impacts on the microclimatic variables. These changes in the land surface characteristics, in turn, result in measurable variations in microclimatic variables such as air temperature and relative humidity (Yang & Wang, 2019). A marked alteration in air temperature and relative humidity was recorded in the current jhum cultivation site as compared to the other land use systems. This could be explained by the complete removal and burning of the vegetation as part of the preparatory phase of shifting cultivation, which exposes the soil and alters the microclimate. Hence, the hottest and driest condition was observed in the current jhum cultivation site. Consistent with previous observations, the temperatures were increasingly buffered with greater vegetation cover, with the natural forest exhibiting the lowest temperature among the land use types (Chen et al., 1999; Luskin & Potts, 2011). The secondary forest, characterized by a greater structural complexity and higher species diversity exhibited a lower mean air temperature than the monoculture plantations of oil palm, areca nut, and teak. The results of the present study align with findings from Indonesia, where natural forest stands and rubber-based agroforestry systems exhibited reduced temperatures and increased humidity compared to oil palm and rubber monocultures (Badu, 2016). The present study revealed that among the plantations, oil palm had the lowest mean air temperature and highest humidity. The sparse canopy due to compact leaf clusters concentrating in the upper crown and slender stems exposes the understory of the areca nut plantation to greater solar radiation, which in turn results in increased temperature and reduced humidity. Although teak develop large crowns, the deciduous nature and wider spacing result in lower canopy overlap and greater light penetration in the understory. In contrast, mature oil palm plantations have greater

canopy cover, owing to their complex, broad fronds and evergreen habit, exhibited a stronger microclimate buffering effect compared to the other two plantations. This reflects the influence of vegetation through canopy density, combined with its biological and structural diversity, which together modulate the local microclimatic conditions (Báldi, 1999; Richter et al., 2022). The study conducted in Costa Rica also showed that temperature and vapor pressure deficit (estimated from air temperature and humidity) were the lowest in the forest understory, while the opposite pattern was observed in the clearings (Fetcher et al., 1985). Canopies absorb and reflect a significant portion of the incoming shortwave radiation of the sun, which, combined with the enhanced evapotranspirative cooling, resulting in a cooler conditions in the understory. On a global scale, this process has been shown to reduce the understory temperature by an average of 4.1 °C compared to the open fields (Frenne et al., 2019).

Studies have shown that the buffering effect of tree cover is particularly evident during the summer season (Greiser et al., 2018). This is supported by the current study, where air temperature was lowest in the natural forest and highest in the current jhum and teak plantation during the pre-monsoon season when temperatures peak in the region. This pattern is attributed to the clearing and burning of vegetation in jhum and the deciduous habit of teak which shed its leaves during this period. The enhanced thermal buffering capacity of the natural forest, especially during the pre-monsoon season, could be explained by the greater species diversity and more complex structural attributes than the modified land use systems (Gillerot et al., 2022). While plantation forests do exhibit some degree of buffering effect, it is comparatively lower due to their reduced structural complexity and species heterogeneity. Similarly, mixed stands showed increased ability to regulate microclimate compared to pure stands (*Acer platanoides*, *Tilia cordata*, *Quercus robur*, and *Carpinus betulus*) in the eastern part of Austria (Steinparzer et al., 2025).

The relative humidity across all land use systems displayed the following seasonal pattern- pre-monsoon < post-monsoon < monsoon. The notable increase in humidity during the monsoon period could be attributed to the strong wind carrying moisture laden wind from the oceanic region to the landmass, resulting in

precipitation and high moisture content. The results also revealed that the primary and secondary forests maintained higher relative humidity even during the dry pre-monsoon season. This reflects the superior microclimate regulating effect of diverse and complex canopy structure of mixed forests compared to monoculture plantations and the open, tree-less jhum cultivation sites. The regulating effects of forest on microclimatic variables have significant implications for the ecosystem functioning, biodiversity conservation, and species performance. Forest canopies regulate air temperature, humidity, and light conditions, creating stable and favorable microhabitats that support diverse organisms and ecological processes. The buffering effect becomes extremely crucial during extreme climatic conditions such as heat-wave by reducing the negative impacts on the biodiversity, human health and the entire ecological processes and functions (Frenne et al., 2019).

Soil physicochemical parameters as affected by land use, seasons, and depth

All soils under the selected land use systems were classified as belonging to the ‘sand’ textural class based on the proportion of sand, silt, and clay. The observed increase in soil temperature from forest to plantation to jhum cultivation could be attributed to the progressive decline in canopy cover from forest to jhum, as forest trees play a crucial role in reducing soil temperature through shading and regulation of microclimate. This is in line with the findings of similar studies (Alem et al., 2020; Kumar et al., 2018; Tanga et al., 2014). The seasonal variation in soil temperature observed in the study was consistent with the reports from the inner Mongolia where soil temperature reached its maximum value in the summer months and reduced in the winter season (Chang et al., 2021). This significant seasonal trend in soil temperature indicated the influence of solar radiation, air temperature, humidity, and moisture on soil thermal condition (Islam et al., 2015; Tang et al., 2022). The increased soil temperature during the pre-monsoon season could be attributed to the combined effect of high solar irradiance and low precipitation prevailing during the period. Conversely, reduced soil thermal condition was recorded in the monsoon and post monsoon seasons, corresponding with the decline in air temperature and increase in soil moisture during the period. The negative relationship between soil temperature and moisture content was also observed in the present study. Tang et

al. (2022) reported that air temperature and soil moisture were the most significant factors influencing soil temperature across three different land use systems in the Loess hilly region of China. In addition, Lozano-Parra et al. (2018) stated that soil temperature is inversely associated with soil moisture and that soil under tree canopies recorded lower temperature than the grassland. Moreover, the findings also revealed that natural forest with the most tree cover has the lowest seasonal variation in soil temperature, while the jhum cultivation with the least vegetation cover has the highest seasonal variation, highlighting the regulating effect of vegetation cover. In contrast to the findings of Tang et al. (2022), which reported depth-wise variation in soil temperature, the present study revealed no significant variation in soil thermal condition between the sampled depth. This discrepancy may be due to the shallow sampling profile employed in the current investigation as compared to Tang et al. (2022), potentially limiting the detection depth-wise variation.

The results of the present study revealed that land use change has significant impact on seasonal soil properties. The bulk density is a vital indicator of soil compaction and health, reflecting the suitability of plant growth and establishment. The mean value of soil bulk density ranged from 1.2 – 1.4 g/cm³ which are suitable for plant growth; however the variation in the soil BD was not statistically significant across the land use systems. Similar findings were also reported by Moges et al. (2013) in Ethiopia. In contrast, Molla et al. (2022) reported that soil bulk density was significantly lower in the natural forest (1.06 g/cm³) than plantation forest (1.17 g/cm³), cultivation land (1.31 g/cm³), and grassland (1.18 g/cm³). Similarly, in the Kolasib region of Mizoram, India, the forest site recorded significantly lower BD compared to the areca nut plantation, rubber plantation, teak plantation, and shifting cultivation site (Lungmuana et al., 2019). In addition, Özdemir et al. (2022) stated that other soil properties and management practices have significant impact on the soil bulk density. The seasonal variation in bulk density was observed to be statistically significant across all land use types, similar observations were also reported in the semi-deciduous northern sub-tropical forests of Nagaland (Semy et al., 2023) and in southern New Mexico, United States of America (Omer et al., 2018). The seasonal variation in the soil bulk density observed in the present study could be explained by the seasonal organic matter dynamic and soil moisture content. Significant depth-

wise variation in soil bulk density was observed exclusively under the natural forest site, whereas the other land use systems did not exhibit statistically significant vertical difference. The observed increase in soil bulk density with depth in forest soils was also confirmed by other studies (Grüneberg et al., 2014; Lepcha & Devi, 2020; Lungmuana et al., 2019). This trend could be attributed to the decline in soil organic matter concentration with depth coupled with the weight of the overlying soil profile exerting pressure on the lower soil depth (Lepcha & Devi, 2020). Consistent with the present findings, Schrumpf et al. (2011) reported that within the human dominated land use system (such as cropland) soil bulk density showed little variation with depth.

Several factors are known to influence soil moisture content such as topography, seasonal climate conditions, land use, vegetation, and other soil properties. Previous researches have reported that soil moisture content is significantly influenced by change in land use system (Agbeshie et al., 2025; Zhang et al., 2024). Conversely, the current study revealed no significant variation in soil moisture content across the different land use types. However, the seasonal soil moisture content under each land use varied significantly at $p < 0.05$. The variations in the soil moisture content aligned with the variations in precipitation, that is, the peak moisture content during the monsoon and the drastic decline in the pre-monsoon seasons reflects the influence of precipitation on soil water content. Higher rainfall events in the monsoon season directly increase the soil moisture content, whereas the low rainfall event during the pre-monsoon period coupled with low humidity led to the reduction in soil moisture content (Liu et al., 2021). Rainfall influence on soil moisture content has been shown to be more prominent in the upper soil compared to the deeper soil profile (Li et al., 2022; Liu et al., 2024), and the present investigation, with its shallow sampling depth exhibited a similar pattern. Although some studies have reported significant vertical variation in soil moisture content (Dai et al., 2022; Liu et al., 2021); the present study did not show depth-wise variation. In the Pisha sandstone hillslopes of China, Zhang et al. (2020) also reported the absence of variation in the vertical distribution of soil moisture particularly at the 0–50 cm soil depth.

The significant land use variation in soil water holding capacity observed in the present study is in accordance with the findings of (Zhang et al., 2021) in the Chinese Loess Plateau. According to Abdallah et al. (2021), soil WHC is governed by land use and management practices, as well as soil properties like texture, organic matter, porosity, and others. In the present study, WHC was notably greater in land use systems where SOM content was most abundant, indicating the positive association between SOM and the soil's ability to retain water (Gómez-Paccard et al., 2015; Minasny & McBratney, 2018). Additionally, the effect of increased SOM content on WHC is more pronounced in coarse-textured soils, such as the sandy soil, recorded in the present study site. Environmental conditions and soil management systems resulting in increased SOM contribute to greater soil water conservation and retention capacity. Whereas, a decrease in SOM content reduces soil water availability, which can negatively affect the sustainable productivity of the land (Abdallah et al., 2021). A clear seasonal trend in WHC was observed under the natural forest, secondary forest, and teak plantation site. This seasonal pattern in WHC corresponds closely with the seasonal changes in the measured SOM within these land use systems, further highlighting the critical role of SOM on soil water retention capacity. Under the natural forest site, the water holding capacity was significantly greater at surface (0 –10 cm) than the lower depth soil (10 – 20cm). This could be explained by the higher concentration of organic matter in the surface layer within the natural forest site. SOM and SOC govern several other soil properties which in turn influence the capacity of soil to retain water (Bordoloi et al., 2018).

The soil reaction analysis revealed that soils across the studied land use types were acidic with pH value ranging from 4.9 – 5.3. The observed values are within the range reported from different parts of Mizoram (Kenye et al., 2020; Lungmuana et al., 2019; Manpoong & Tripathi, 2019; Wapongnungsang et al., 2021) and northeast India (Saha et al., 2012; Shimrath et al., 2015; Temjen et al., 2022; Yam et al., 2021). Nearly 25 million ha of soil in India is acidic with pH value under 5.5 and another 23 million ha exhibits pH value ranging from 5.6 to 6.6. A little more than half (54%) of the total acidic soils are distributed in the northeastern region of the country (Kumar

et al., 2021). Natural forest recorded significantly lower pH value compared to the other land use systems, this observation is in line with the findings of (Islam & Weil, 2000) in Bangladesh. The acidic nature of soil in the present study could be attributed to the leaching of basic cations from the soil profile, especially in areas like Mizoram that experience heavy rainfall during the southwest monsoon period (Kenye et al., 2020; Kumar et al., 2021; Shimrarh et al., 2015). Additionally, management practices such as the use of acid producing fertilizers like aluminum-based fertilizers could result in acidic soil (Liu et al., 2010; Yu et al., 2011). However, considering the minimal use of fertilizers in the traditional land use systems in Mizoram, precipitation induced leaching could be the principal factor for soil acidity. Several reports have stated that burning have an increasing impact on soil pH (Islam & Weil, 2000; Lungmuana et al., 2019; Shimrarh et al., 2015), which in accordance with the current study where shifting cultivation site and other plantation sites have higher pH value than the natural forest site. The seasonal variation in soil pH value was significant across all land use systems except for the areca nut plantation site. The observed seasonal pattern in pH supports the existing knowledge of rainfall influence on soil pH, as all the land use systems exhibited the lowest pH during the monsoon season when rainfall is the highest. Majority of the land use systems showed a gradual increase in the pH from monsoon to the post-monsoon season, and reaching their peaked value in the pre-monsoon season. This trend is particularly significant for the jhum cultivation site where cutting and burning of plant biomass takes place in the pre-monsoon period.

The spatial variability of soil carbon has been established by various studies (Assefa et al., 2017; Choudhary et al., 2016; Weissert et al., 2016). Built up of soil organic carbon content in any land use system is the trade-off between carbon inputs (through litter fall, root exudates, crop residues, and root biomass) and carbon losses (respiration by organisms), influenced by biomass turnover, their quality, and rate of decomposition (Raich & Schlesinger, 1992). Management practices and disturbances have been identified as factors influencing the distribution of SOC and SOM (Ramesh et al., 2019). Land use systems like the natural forest, involving lesser disturbance on soil typically results in higher accumulation of organic carbon and

organic matter, as is evident from the current research. The present study reported that the conversion of forest to alternate land use systems resulted in decreased organic carbon and organic matter concentration in the soil which is consistent with the findings of Delelegn et al. (2017) in northern Ethiopia. The SOC and SOM increased in the following order: T < SF < AN < OP < J < NF; continuous litter inputs from the aboveground and belowground biomass could be the reason for high organic carbon and organic matter accumulation in the forest soil (Assefa et al., 2017). The higher concentration of SOC in the current jhum site may be attributed to the addition of burnt and partially burnt phytomass during the slash and burnt process. Similar findings were also reported by Sahoo et al. (2019) in Mizoram and by Binarani et al. (2009) in the Kangchup hills of Manipur. The study reported that secondary forest exhibited lower SOC concentration than the oil palm and areca nut plantation, which contrasts with the findings of Lungmuana et al. (2019) who reported that higher carbon concentrations in secondary forest than plantations like rubber, teak, and areca nut. On the other hand, eight year old *Acacia mangium* plantation recorded relatively consistent carbon content with secondary forest and pasture land in Vietnam (Sang et al., 2013). The observed lower SOC and SOM content in the teak plantation site when compared with natural forests was also reported by previous studies (Aborisade & Aweto, 2007; Amponsah & Meyer, 2000; Thomas et al., 2021). A study by Jose & Koshy (1972) concluded that conversion of natural forest to teak plantation significantly decreased the concentration of organic matter in soil in the first 15-30 years of plantation which did not recover to the natural forest levels even after 60 years of age. The reduced SOC and SOM content under the teak plantation could be attributed to the absence of undergrowth, as suggested by Boley et al. (2009). The SOC and SOM also exhibited a distinct seasonal pattern across all land use systems, further corroborating previous studies that SOC and SOM can undergo significant seasonal changes that differ with land use types and management practices (Kaur et al., 2021; Semy et al., 2021; Wuest, 2014). In the natural forest site, the seasonal peak in soil organic carbon and organic matter during the post-monsoon period could be attributed to the accelerated rate of litter decomposition with the onset of the monsoon rain. Elevated temperature and moisture in the monsoon season promotes the growth and metabolic activities of soil

microorganisms, which results in the accumulation SOC and SOM in the subsequent season, that is the post-monsoon (Singh et al., 2025). The vertical distribution of soil organic carbon and organic matter revealed that the accumulation of organic carbon and organic matter were significantly greater in the surface across all land use types except for teak plantation. The decreasing pattern of SOM and SOC concentration with depth is typical to the general trend (Robinson & Benke, 2023) and is supported by several studies (Kumari et al., 2022; Shapkota & Kafle, 2021; Xing et al., 2023). The greater accumulation of SOC in the surface soil could be largely attributed to continual inputs of fresh organic matter coupled with high biological activity in the topsoil (Liu et al., 2023). Organic carbon exhibits greater stability in the deeper subsoil layer, whereas carbon in the topmost layer is more susceptible to variations driven by land uses types, seasonal changes and other environmental factors (Kumari et al., 2022; Schrumpf et al., 2012), which underscores the importance of monitoring the organic carbon dynamics in surface soil.

The distribution of soil available macronutrients (N, P, and K) was found to differ significantly across the different land use systems. Relatively higher available macronutrients in the jhum cultivation are mostly due to the ash from the burnt vegetation biomass that acts as fertilizer (Lungmuana et al., 2019). Arunrat et al. (2023) and Thokchom et al. (2024) also reported enhanced nutrient level in shifting cultivation sites specifically in the post-burning period. However, the initial increase in nutrient contents post burning is short-lived as nutrients tend to deplete when the site is abandoned and left to fallow (Thokchom et al., 2024). It is also important to note that shifting cultivation sites are susceptible to erosion as fire alters soil structures and increase the risk of erosion (Arunrat et al., 2024). In line with the findings of Lungmuana et al. (2019), arecanut, teak, and oil palm plantations exhibited lower nutrient contents than the natural forest. Nutrient release in soil is significantly influenced by the quality and quantity of litter inputs. Natural forest with its diverse and large litter inputs could explain higher nutrient contents than the monoculture plantation sites (Widyati et al., 2022). The slow decomposition rate of teak litter which is rich in insoluble lignin resulting in slow return rate of nutrients could be the reason for low nutrients content in the teak plantation site (Cavalcante et

al., 2020; Das & Mondal, 2016). Similarly, removal of understory vegetation in oil palm and areca nut plantation coupled with homogenous and reduced biomass from the trees could explain decreased macro nutrients under these sites (Formaglio et al., 2021). The highest seasonal nutrient concentration during the post-monsoon season in majority of the land use systems reflects the influence enhanced microbial activity due to the warm and moist soil coupled with the increased litter fall attributed to heavy rain and windy conditions during the monsoon season. Increased precipitation during the monsoon often leads to nutrient leaching from the soil, which can explain the observed reduction in nutrient concentrations during this period. Additionally, nutrient loss from the topsoil is exacerbated by surface runoff during peak monsoon events, further depleting soil fertility (Kleinman et al., 2006). The decreasing pattern of soil macronutrients with depth could be attributed to the decrease in organic matter along the soil profile (Mandal & Ghosh, 2021).

Land use patterns effect on seasonal soil quality index

The selection of variables such as pH, SOC, and available P for assessing the SQI reflected the significant influence of these soil parameters on soil functions for the study region. The reduction of variables using MDS method helps to improve accuracy, checks redundancy, and enhance the overall efficiency (Huang et al., 2021). The type and number of parameters retained as MDS varied across regions. In accordance with the current study, pH, SOC, and available phosphorus were also retained as MDS for SQI assessment in the Yellow river delta wetland, China (Zhang et al., 2022). Meanwhile, the available nitrogen and electrical conductivity constituted the MDS for SQI analysis in the semi-deciduous northern tropical forest of Nagaland, India. The dominant influence of pH, SOC, and available phosphorus on soil function is well recognized by several studies (Blanco-Canqui et al., 2013; Muindi, 2019; Shukla et al., 2006). Soil pH, owing to its strong influence other soil parameters and biogeochemical processes, is often described as the “master soil variable”. It regulates the soil microbial diversity and activities, the availability of soil nutrients and mineralization of organic matter in the soil (Neina, 2019). Soil organic carbon (SOC) plays a vital role in improving soil quality. It enhances the biological, chemical, and physical properties of soil by stimulating microbial

activity, maintaining optimal soil pH, and increasing cation exchange capacity. Additionally, SOC improves water retention, reduces soil compaction, and promotes the formation of aggregates (Blanco-Canqui et al., 2013). Phosphorus has high mineralization process and is the second most critical nutrient limiting plant growth and overall ecosystem productivity. Temjen et al. (2022) also selected available phosphorus as soil quality indicator in India.

The higher additive and weighted SQI values reported from the surface soil (0 – 10 cm) across all land use systems could be attributed to higher organic content, greater microbial activity, and enhanced nutrient availability, resulting from the accumulation of plant residue in the topsoil. The observed higher SQI in the upper soil is consistent with the findings from Iowa, USA, where 0 – 5 cm exhibited better SQI than the 5 – 15 cm layer (Li et al., 2021). The dominant soil quality indicators such as SOC and available P selected in the study showed significant land use pattern at 0- 10 cm , this could explain the variation in the SQI across the different land use systems, with the highest SQI under the natural forest during the post-monsoon season. The higher SQI under the natural forest could be attributed to the greater species diversity and structural complexity, resulting in increased and diverse litter input to the forest soil (Widyati et al., 2022). Owing to its greater similarity to the natural forest than the monoculture plantations in terms of species richness and structural diversity, the secondary forest exhibited the second highest SQI value after the natural forest. Furthermore, the monsoon rain provide favorable conditions, resulting in enhanced microbial activity, which in turn accelerates the process of decomposition could be the reason for the increased SQI value during the subsequent season (post-monsoon) (Singh et al., 2025). This observed pattern is consistent across all land use except for the current jhum cultivation site and teak plantation. The clearing and burning of vegetation during the pre-monsoon period as part of the jhuming process resulting in the addition of ash and partially burnt phyto-biomass to the soil (Lungmuana et al., 2019). The resultant effect is the reduction of soil acidity, a prevailing issue in the hilly northeastern part of the country (Kumar et al., 2021), and increased nutrient content. This may be the reason of increased SQI during the period under the current jhum. Teak is a deciduous tree, shedding its leaves during the pre-monsoon period. The increased microbial activity working on

the decomposition of litter accumulated during the previous season could be a plausible explanation for seasonal SQI peak during the monsoon period (Ochoa-Hueso et al., 2020).

Teak and oil palm plantations at 10 –20 cm recorded the lowest additive and weighted SQI at during the monsoon season. This reflects poorer soil condition at this depth compared to the surface layer, likely due to factors such as nutrient leaching and soil compaction (Li et al., 2021). In contrast to the topsoil layer, the secondary forest exhibited the highest additive and weighted SQI at the sub-surface layer. The results of the present study revealed that forest soils (both natural and secondary) exhibited better quality than the modified land use systems at the surface and sub-surface layers. This highlights the crucial role of forest ecosystems in regulating and enhancing soil functions through diverse vegetation cover, minimal soil disturbance, and efficient nutrient cycling. It also emphasizes that conversion of forests to alternate land use systems have obvious negative impacts on soil and often lead to soil degradation. Thus, the findings underscore the critical importance of conserving and protecting forests to maintain soil quality and ecosystem functions, particularly in regions like Mizoram that experience an increased land use shifts.

Tree diversity and community characteristics

The 122 tree species recorded highlights the richness of Dampa tiger reserve in terms of biodiversity and underscores its importance as a biodiversity hotspot in Mizoram. This value is comparable to findings from other semi-evergreen forests such as- 108 species from the Kolahat reserve forest, Assam (Borah et al., 2015), Meghalaya, 127 species from Lengteng wildlife sanctuary, Mizoram (Sailo, 2019), and 124 species from Reiek, Mizoram (Devi et al., 2018). In contrast, it is greater than 65 species from Pala wetland reserve, Mizoram (Nohro & Jayakumar, 2020), 90 from Sathymangalam tiger reserve, Tamil Nadu (Sathya, 2017), and 80 species from Sharvarayan hills of Eastern Ghats, India (Kadavul & Parthasarathy, 1999). Meanwhile, Tynsong et al. (2022) recorded 146 species from Meghalaya, India, 168 species from the Swer sacred grove (Mishra et al., 2004), and 148 species from Western Ghats by Ayyappan & Parthasarathy, 1999. Floristic composition of an area is strongly influenced by the combined effect of precipitation patterns and

temperature, alongside important edaphic and biotic factors (Tripathi & Tripathi, 2010). Owing to its bio-geographical location within the Indo-Burma biodiversity hotspot, the area experiences favorable climatic conditions and has diverse habitat, supporting a rich diversity. These factors combined with the strict protection regime of the reserve contribute to high species richness in DTR (Upadhaya et al., 2003).

Varying degree of protection and management regimes are known to determine the level of anthropogenic disturbances in a forest, which in turn shape plant communities by affecting their diversity, composition, and stand structure (Bentsi-Enchill et al., 2022; Tenzin & Hasenauer, 2016). The findings of the present study revealed that tree species diversity, composition, and measured community parameters differ significantly between the two conservation zones within Dampa tiger Reserve. The higher species richness recorded from the core zone could be attributed to its rigid protection, which minimizes anthropogenic disturbances such as logging, resource extraction, and grazing. In contrast, the buffer zone is subjected to a wide range of human activities including traditional shifting and settled agriculture, grazing and logging, and NTFP extraction, which might explain the lower species richness observed in this zone. This is in line with findings from previous studies where forests with minimal disturbances are characterized by greater species richness. Dao et al. (2016) reported 193 and 173 tree species in the core and buffer zone of Ta Xua nature reserve, Vietnam. Similarly, in Reiek's tropical semi-evergreen forest, Lalzarzovi (2014) identified 91 tree species in the protected core zone, and 71 species in the buffer zone of the community forest.

Various diversity indices offer valuable insights into the richness, evenness, and composition of species within an ecosystem. The Shannon-Weiner diversity index values from the natural forest and secondary forest indicate that DTR supports a diverse and well-balanced assemblage of tree species (Mansingh et al., 2025). This value is comparable to those reported from Pala wetland reserve, Mizoram (3.73) by Nohro & Jayakumar (2020), Hollongapar gibbon wildlife sanctuary, Assam (3.55) by Sarkar & Devi (2014), and Sathyamangalam tiger reserve, Tamil Nadu (3.48) by Mani & Jayakumar (2017). However, it is higher than the values reported from the Swer sacred forest (2.2), Meghalaya (Mishra et al., 2004). According to previous

studies, the Simpson's dominance index in tropical forests of India ranges from 0.02 to 0.93 (Garkoti & Borah, 2015; Kadavul & Parthasarathy, 1999; G. Mishra & Das, 2019; Nautiyal & Manish, 2025). The natural forest in core zone of the reserve exhibited higher diversity and evenness indices, whereas the Simpson dominance index was higher in the buffer zone, suggesting the presence of a more balanced and heterogeneous community in the core area. Similar trend was reported by (Lalfakawma et al., 2010), where undisturbed stands of Zobawk forest showed greater species diversity as compared to the disturbed stands. The low Shannon-Wiener and high dominance indices recorded in the plantation sites were largely influenced by management practices.

The overall dominance increased from the core zone to the buffer zone with highest species dominance in the plantation sites, suggesting that disturbances create environmental conditions in the buffer zone that are favorable to certain species over the others. This leads to a reduction of species diversity in the buffer zone compared to the core zone (Lolila et al., 2023). Although, *Schima wallichii* emerged as one of the most dominant species in the natural and secondary forests, there was a notable difference in the dominant species between them. The dominance of *Gmelina arborea*, *Macaranga indica*, and *Callicarpa arborea* in the buffer zone was expected because of their pioneer nature and ability to establish themselves in disturbed areas (Fern, 2024). The dominance of pioneer species in a highly disturbed site was also reported from Ghana, West Africa (Bentsi-Enchill et al., 2022). The core zone's dominant species are a mixture of both late successional and climax species such as *Schima wallichii*, *Mesua ferrea*, *Syzygium cumini*, *Macropanax undulatus*, and *Magnolia oblonga*. These are typical of mature and old growth forest (Fern, 2024), indicating the absence of recent disturbance and relative stability of the forest. In addition, a marked shift in dominant family was also observed from the core zone to the buffer zone. This finding is consistent with report from other studies (Mishra et al., 2004; Parthasarthy & Karthekeyan, 1997). Natural forest and secondary forest shared the highest Sorensen similarity index because their species composition overlaps more than with any other land- use types. As succession proceeds, the structure and microenvironment of secondary forests become more similar to natural

forest, favoring the establishment of the same suite of forest interior species (Korkiatupa et al., 2025). The low similarity index between natural forest and the modified land use systems could be attributed to the level of disturbance and management regimes.

There was significant decrease in stands count per area and the basal area from the natural forest core zone to the secondary forest in the buffer zone. The observed pattern aligns with the findings from Arunachal Pradesh, India where stem density and basal area are comparatively higher in undisturbed forest than disturbed stands (Bhuyan et al., 2003). The estimated stand density is closely aligned with those reported from the Eastern Ghats by Sahu et al. (2019) at 390–433 ind. /ha, Mudumalai Wildlife Sanctuary by Chintala et al. (2008) at 110–406 ind. /ha and the tropical forest of Nagaland by Ao et al. (2023) at 313–330 ind. /ha . In contrast, higher values have been reported by Suchiang et al. (2020) from sacred groves of Meghalaya at 1152 ind./ha, by Sudhakar Reddy et al. (2011) from Eastern Ghats (709 ind. /ha) , and by Rasingam & Parthasarathy (2009) from Little Andaman island at 935 ind. /ha. The basal area reported in the core zone is comparable to findings from Little Andaman island at 55 m²/ha (Rasingam & Parthasarathy, 2009) and from the Pala wetland reserve at 59 m²/ha (Nohro & Jayakumar, 2020), but lower than the 61.72 m²/ha from the forests of Meghalaya's southern slopes (Tynsong et al., 2022). Whereas, the secondary forest zone exhibited a significantly lesser basal area than those reported from undisturbed forests, but is closely aligned with the findings from a moderately (22.98 m²/ha) and highly disturbed (22.21 m²/ha) stands in Odisha (Sahu et al., 2019), and a moderately disturbed forest in Meghalaya at 18.6 m²/ha (Mishra et al., 2004). The variations in stand density and the basal area in the plantation forests in the buffer could be largely attributed to the management practices, such as plantation density, thinning regimes, and age of the plantations. The lower stand density and basal area in the current jhum site was mainly due to the clearing and burning of vegetation, removing both mature trees and understory, leaving only scattered trees uncut and unburned.

The distribution of trees girth classes acts as an important indicator for evaluating stand structure and dynamics, successional stages, regeneration status, and overall

species composition within a forest (Garkoti & Borah, 2015). The girth class distribution in the core zone exhibited a reverse J-shaped curve, with high density of younger individuals, indicating an actively regenerating forest. However, the presence of large girth trees (>330 cm) also suggests relative stability and structural complexity (Sarkar & Devi, 2014). The pronounced dominance of biomass by the large girth trees, as observed in the core zone is a typical characteristic of a mature, old growth forest. The predominance of small-girth trees in stand density, coupled with the disproportionate contribution of basal area by large trees observed in the present study, aligns with patterns reported from Meghalaya (Upadhaya et al., 2003). The dominance of smaller girth individuals and absence of mature trees (>240cm), yielding a reverse J-shaped curve reflects the active regeneration status of the secondary forest. The decline in stand density, basal area, and overall ecological stability from the core to the buffer zone could be attributed to the prevailing human disturbances in the buffer zone owing to the difference in the conservation and management status between the two zones (Joshi, 2020). The linear regression showing significant positive association between basal area with tree density and species richness conforms to Jaiswal & Jayakumar (2024) and Barrufol et al. (2013). It was found that stem density showed stronger positive relationship with basal area ($R^2=0.24$) than species richness ($R^2=0.18$). Nevertheless, the findings indicate that, higher stem abundance and greater species richness contribute to higher biomass accumulation (Dyola et al., 2022). In addition, the positive relationship between species richness and tree density suggests that maintaining higher stem abundance is required for increased species richness within a forest.

The presence of tree species in an area is influenced by multiple factors including environmental variables as well as the structural, functional, and conservation attributes of the species (Kambo & Danby, 2018). DBH emerged as a significant predictor of tree absence in the buffer zone. According to the logistic regression, large trees exhibited increased odds of absence. This pattern is likely a result of selective felling of large trees for timber combined with shifting cultivation pressure and the slow growth rate of native trees. Meanwhile, the results revealed that Red-listed status decreased the probability of absence. This interesting

observation is contradictory to the finding from Ta Xua nature reserve, where red-listed species increased the odds of tree absence in the buffer zone (Dao et al., 2016). This suggests that despite their global conservation status, some of the Red-list species may have a stable and healthy local population. Furthermore, stem density was shown to be a significant determinant of absence in the buffer zone at both the tree and species level. The low density species missing from the buffer zone may be linked to their narrow distribution pattern combined with constant exposure to human-induced disturbances. The adverse impact of disturbance on forest community due to land use change is evidenced by the reduced overall diversity, structural stability, and complexity from the core zone to the buffer zone.

Drivers of human-wildlife conflict and people's perceptions

Land use change, forest fragmentation, and habitat destruction have intensified the frequency and magnitude of negative human and wildlife interactions, also known as human-wildlife conflict (HWC) (Muleta GurMESSA et al., 2024). Previous studies from different parts of the world indicated that human-wildlife conflict is more intensified in and around protected areas (Alexander et al., 2015; Carter & Allendorf, 2016; Karanth et al., 2012; Kidane et al., 2024). Consistent with these reports, incidents of HWCs were reported by respondents in a survey across four villages located along the reserve's fringe. However, the proportion of respondents experiencing the impact of negative human-wildlife interaction was lower than those reported from Rajasthan, India (77.5%) (Karanth et al., 2019) and from northern Ethiopia (95%) (Kidane et al., 2024). Four common types of conflict have been identified - crop damage, livestock depredation, human casualty, and property damage. Among these, crop raiding emerged as the predominant form of HWC worldwide (Kidane et al., 2024). The finding of the present study is in line with the global trend, with 70.57 % of reported HWC is in the form of crop raiding, followed by human attack, livestock depredation, and property damage. Similarly, Milda et al. (2023) also reported that in the Eastern and Western Ghats region of India, 98.8% of human-wildlife conflict is in the form of crop raiding, 1.5% in the form of property damage, and the remaining 0.2% was in the form of human attack.

Crop raiding

Crop raiding by wild animals may arise from various reasons and may vary from one region to another. In addition, spatial and temporal variations in crop raiding have been reported by previous studies (Mamo et al., 2021; Milda et al., 2023; Naha et al., 2020). Furthermore, species involved in crop damage also exhibit regional variations- in the southern and northeastern part of India, elephants and wild pigs emerged as the most frequent crop raiders, whereas blackbucks and blue bull in the western part of the country like Gujarat (Manral et al., 2016; Anand & Radhakrishna, 2017). Additionally, birds such as parakeet, munia, and weaver birds, and primates like macaques, gibbons, and langurs were reported to have significant damage on crops in different parts of the country (Anand & Radhakrishna, 2017). The variations in crop raiding species across regions may be attributed to species abundance, feeding ecology, and the degree of habitat loss or fragmentation (Naughton-Treves, 1998; Sukumar, 1990). The present study identified wild pigs as the most significant crop raiders in the DTR area, aligning with findings from other regions (Hazra, 2023; Pandey et al., 2019). Rodents were also revealed as one of the principal contributors to crop damage in the study. Damages caused by rodents are often underestimated because of their less charismatic value and low conservation appeal (Lauret et al., 2020). Moreover, rodents-induced damages are generally less conspicuous and gradually occurring rather than sudden and drastic damage caused by larger animals. Ulman et al. (2020) also reported that rodents' damage was the most significant in traditional agroforestry systems in Assam. The remarkable adaptability, high reproductive potential, and generalist nature of both rodents and wild pigs make them one of the most problematic species worldwide (Bengsen et al., 2017; Wondifraw et al., 2021). The study also highlighted the notable seasonal pattern of crop raiding, which peaked during monsoon and autumn seasons, when crops are mature and ready to be harvested. It was also found that the preferred time for crop raiding is during nocturnal hours when humans are absent in the fields. A similar trend was also reported from elsewhere (Gross et al., 2018; Podgórski et al., 2013). In addition, the results showed that households practicing the traditional shifting cultivation were more vulnerable to crop raiding than those involved in settled farming. The probable reason could be the distinct characteristics of two

agricultural types. This is further explained by the regression model that showed crop type as an important predictor of crop damage. Households that cultivate food crops like rice, maize, cassava, and local vegetables in the traditional shifting cultivation farms, and horticulture crops such as bananas, oranges, pineapples, and, sugarcane, and oil palm had higher probability of being raided than crops like area nut grown in settled farms. The higher vulnerability of these food crops to raiding may be explained by their palatability coupled with their nutritional content (Asaye et al., 2024). However, the intercropping of food crops with areca nut or other non-palatable crops significantly reduced the probability of damage, as suggested by lower estimates. The distance of fields from the core zone of the reserve was found to have significant positive association with losses. The observed trend contradicts with other reports where farms that are closer to protected areas were more susceptible to damage (Eustace et al., 2022; Karanth et al., 2013). In contrast, Di Fonzo (2007) and Monney et al. (2010) found no significant correlation between the extent of crop loss and farms' proximity to protected areas. The likely explanation for the observed pattern in the study was that all the animals responsible for crop damage were not exclusively from the reserve. The observed positive association between implementations of protective measures and crop loss may likely arise due to past experiences of loss by households, resulting in adoption of mitigation measures.

Livestock loss

The data from the survey revealed that fewer incidents of livestock depredation occurred in DTR as compared to other regions in India (Ankit et al., 2021; Chatterjee et al., 2022; Kumar et al., 2022). This could be attributed to the very low population of large predators such as tigers and leopards, which are frequently documented as key species in livestock predation (Singh & Macdonald, 2017), coupled with the predominant practice of housing animals in designated enclosures. The presence of smaller predators such as Asiatic golden cats, marbled cats, jungle cats, clouded leopards, leopard cats, jackals, wild dogs have been documented by (Gouda et al., 2021; Sethy et al., 2016; Singh & Macdonald, 2017); only leopard cats and jackals were reported to be responsible for livestock predation. In addition, depredation of domestic animals was exclusively on chicken. The regression model

indicated that free-ranging chickens were more vulnerable to predation by wild animals. This is in line with the findings of Alexander et al. (2015) in China where predation of livestock by snow leopard mostly occurred when animals were grazing in the open.

Human casualties and property damage

The study revealed that respondents who were involved in forest-based and farm-based activities suffered casualties due to animal attack, mostly in the form of snakebite. This reflects the vulnerability of those involved in farming to wildlife-induced injury than those with alternate occupations. This underscores the need for sensitization and workshops on snakebite management in the area. Attacks on humans by wild pigs, bears, and elephants were also reported by few respondents, but their percentage is relatively lower than human-snake conflict. Studies from other regions reported higher incidents of human-tiger, human-elephant, human-leopard, and human-bear conflicts than human-snake conflict (Acharya et al., 2016; Baral et al., 2021; Uniyal et al., 2025). In the Indian context, Gulati et al. (2021) revealed that elephants accounted for most of the human casualties. The reported variations in species responsible for human injury could be explained by the wildlife abundance in the area, coupled with underreporting of snake-related conflicts. Large animals such as elephants are typically responsible for property damage, which explains property damage by wild elephant in the area.

Compensation claim

Access to fair and timely compensation is essential to ensure that communities bearing the cost of wildlife-induced damages remain supportive of conservation. Several factors have been identified to influence compensation claims and assess. Around one third (35.21%) of respondents experiencing wildlife-induced damage reported to the authorities and claimed for ex-gratia compensation. This proportion exceeds that of community residing around the four wildlife sanctuaries in Rajasthan, where knowledge of compensation mechanisms was relatively poor (Johnson et al., 2018). Though, a significantly large portion of the respondents claimed to be aware of the compensation schemes and the process involved, their reporting behavior remained relatively low. The lengthy and cumbersome procedure: requiring applicants to submit a written request with

photographic proof of wildlife damage, field verification, and the prolonged delay in the ex gratia payment being deposited into the respondents' accounts were identified as a key factor for underreporting. Geographical location of households played a key role in reporting damage incidents. Residents of West Phaileng exhibited a greater tendency to report HWC incidents and claim financial compensation than those from other villages could likely be due to their geographical proximity to the administrative center, especially the Office of the Field Director, DTR. Karanth et al. (2012) also found that households located in the administrative buffer showed higher likelihood to report HWC incidents in Central India. The observed pattern underscores the importance of ease of compensation claim. Unlike observations from Central India and Southern Western Ghats, the tendency of seeking financial compensation in the present study was not significantly associated with the nature and extent of loss (Karanth et al., 2012; Rohini et al., 2017). This underscores the need to simplify the process of reporting HWC incidents and assessing compensation claims to foster coexistence between human and wildlife in the region.

Perceptions

Socio-economic conditions and personal experiences are among some of the most influential factors shaping people's perceptions on wildlife conservation (Carter & Allendorf, 2016; Choudhury et al., 2019; Sharma et al., 2020). This present study's findings also corroborate with this observation. However, only selected demographic and socioeconomic variables such as education level, age, and village were found to be significantly associated with perceptions. As stated in previous reports, individuals with higher education were more likely to have a more positive perception towards wildlife conservation. This could be explained by enhanced ecological knowledge and increased engagement with environmental awareness among the educated individuals (Kidane et al., 2024; Sharma et al., 2020). Meanwhile, in contrary to the present study, Bhat et al. (2022) observed that university educated respondents exhibited a less positive perceptions than those educated at the primary, secondary, and college level. Although studies from other regions observed the existence of gender gaps in perception, the present studies showed no significant difference between genders (Alexander et al., 2015; Carter &

Allendorf, 2016). The more positive perceptions observed among older individuals could be explained by their greater life experiences, in combination with deeper understanding and connections with the natural environment compared to the younger generations. The older generations may have exposed to greater positive encounters with wildlife, which could have culminated in their positive perception towards wildlife conservations (Basak et al., 2022; Wang et al., 2021). Studies undertaken in different regions have reported that absence of negative interactions and recipients of economic benefits have significant positive influence on perceptions (Bhat et al., 2022; Kansky & Knight, 2014; Karanth et al., 2019). However, the findings of the present study did not agree with this trend. The respondents from West Phaileng and Phuldungsei villages, who are predominantly from the Mizo community, expressed a more negative perception towards conservation than those of Damparengpui and Tuipuibari where the majority is from the Bru community. The observed differences in perception may arise from variations in socio-economic, cultural backgrounds, as well as different levels of exposure to interventions such as awareness campaign. Similar patterns of variation were observed among villages and different ethnic groups (Chaves et al., 2024; Suwannarong et al., 2024). Fostering positive perceptions and attitudes towards wildlife conservation, especially among people living in close proximity to wildlife is imperative for promoting coexistence between man and wildlife.

CHAPTER 6

SUMMARY AND CONCLUSION

The ever increasing anthropogenic demands exert an overwhelming pressure on forest resources, leading to accelerated degradation and deforestation. Two main factors have been identified for forest loss worldwide- extraction of forest resources and conversion of forest to alternate land use systems (FAO, 2020). Around 75 % of the global land surface has been altered by anthropogenic activities, which is strongly correlated with biodiversity loss and disruption of ecosystem functions and services (Pulido-Chadid et al., 2023). The effects of land use and land cover changes extend beyond biodiversity; as such changes exert significant impacts on the climate at the micro, meso and macro scales. Forests function as biophysical thermo-regulators of the microclimate by affecting evapotranspiration and albedo. Conversion of forests to other land use systems will result in higher albedo, absorbing lesser radiation but, drier condition due to the release of net radiation in large amounts as sensible heat (Faye et al., 2014). The quality of soil and its productivity and sustainability relies on the dynamic balance among the biological, chemical, and physical properties which are significantly influenced by land use systems (Nanganoa et al., 2019; Tellen & Yerima, 2018). Characterizing soil quality variations across multiple spatial scales offers valuable insights into the impacts of land management practices on soil health. The responses of different soil quality parameters varied significantly across land use types in their magnitude and direction. Beyond its impacts on ecosystem processes, land use change also alters the spatial distribution and behavior of wildlife. As natural habitats are degraded or converted for agriculture, settlement, and infrastructure, wildlife is increasingly displaced from its native ranges. This often leads to greater overlap between human activities and wildlife habitats, resulting in escalating human–wildlife conflicts (HWC) in many parts of the world. In an effort to counter the declining rate of biodiversity and protect ecosystem structure, functions and services, several protected areas are established across the globe (Geldmann et al., 2019). The effectiveness and potential of a protected area to an extent is a function of the surrounding landscape (Hansen & DeFries, 2007). Studies

suggest that protected areas are threatened by increased human pressure in various forms such as land use change, pollution, invasive species, hunting and other threats (Ghosh-Harihar et al., 2019). The loss of protected area functionality and integrity due to changes in the surrounding landscapes not only weakens biodiversity conservation and ecosystem services but also alters the movement pattern of wildlife. As natural habitats become increasingly fragmented or degraded, interactions between humans and wildlife increase, often resulting in heightened human–wildlife conflict (Distefano, 2003).

Dampa Tiger Reserve (DTR) constitutes the largest protected area in Mizoram, and is home to a rich diversity of flora and fauna. However, like many protected areas in India, the surrounding landscapes of DTR are experiencing extreme anthropogenic pressures from land use change, expansion of human settlements, and habitat fragmentation (Gouda et al., 2021). Such disturbances not only threaten ecosystem sustainability and habitat suitability, but also modify vegetation composition and structure, thereby influencing tree diversity, habitat characteristics, and escalating human-wildlife conflict in and around the reserve.

Given the growing human pressures around the reserve and their ecological consequences, this study seeks to understand how land use changes affect tree diversity, habitat characteristics, and the pattern and occurrence of human-wildlife conflict. In line with this aim, the study was designed with the following specific objectives-

4. To assess the spatio-temporal extent of land use/land cover changes in Dampa Tiger Reserve.
5. To study the microclimate, soil characteristics, tree diversity and community characteristics in the different land use types of Dampa Tiger Reserve.
6. To evaluate perceptions and attitudes of people regarding human-wildlife conflict, and identify the drivers for mitigation measures.

Land Use/Land Cover (LULC) classification was conducted using the Google Earth Engine (GEE) platform, utilizing Landsat 5 Thematic Mapper (TM) and

Landsat 8 Operational Land Imager (OLI) Surface Reflectance data for the dry season periods (February–April) of 2011 and 2021, respectively. Change analysis was performed and LULC maps of 2011 and 2021 were generated. Based on remotely-sensed data and ground validation, six major land use systems were further selected for the assessment of microclimate, soil characteristics, and tree diversity and community characteristics. They are natural forest (NF), secondary forest (SF), current jhum (CJ), Oil palm (OP), Teak, and Areca nut (AN) plantations. To understand the microclimate, ambient temperature and relative humidity was determined using Thermo Hygrometer. Soil samples were collected from two different depths (0–10 cm and 10–20 cm) randomly from each site considering three seasons namely pre-monsoon (January – April), monsoon (May – August), and post-monsoon (September – December) seasons. The collected soil samples were analyzed to determine various physicochemical properties including moisture content, bulk density, water-holding capacity, pH, organic carbon, organic matter, available nitrogen, phosphorus and potassium following standard methodologies. Phyto-sociological sampling was conducted within the core and buffer zone of the DTR. For sampling, 20m × 20m quadrats were laid in each zone following standard quadrat method keeping the physiographic conditions in account (Curtis and McIntosh 1950). Quantitative characters of the community such as spatial distribution, stand density, basal cover, and importance value index (IVI) were calculated following Misra (1968), Mueller-Dombois & Ellenberg (1974) and Magurran (1988). To assess the nature and extent of human-wildlife conflicts and identify factors driving these conflicts, and to assess people's perception on wildlife conservation, four fringe villages located in the buffer zone of Dampa Tiger Reserve were selected namely Damparengpui, Tuipuibari, West Phaileng, and Phuldungsei.

The analysis of land use land cover (LULC) change between 2011 and 2021 in DTR revealed notable shifts in land cover distribution. The spatial distribution of change between the two selected years showed that most of the land use changes are concentrated within the buffer zone of the reserve, where anthropogenic activity seems to be highest. Forest continued to be the dominant land cover in both the year 2011 and 2021, however a decline in forest cover was observed, decreasing from 752

sq km in 2011 to 737 sq km in 2021. In contrast, the rest of the land use categories such as jhumland/barren, built-up areas, and water bodies exhibited an increasing trend over the decade.

The Kruskal-Wallis rank sum test revealed significant air temperature variation across land use systems. The highest mean air temperature was recorded from the current jhum cultivation site, followed by monoculture plantation of areca nut and teak. The secondary forest and oil palm plantation exhibited intermediate value while the lowest value was recorded in the primary forest. Under each land use system, the maximum value was recorded in the pre- monsoon season, followed by monsoon and post-monsoon season. This general pattern was consistent for both the forest sites and the more intensively used landscapes, although the degree of change was not uniform. Across the different land-use systems, clear seasonal patterns in relative humidity was observed, with values peaked during the monsoon period and dropped again afterwards. Although this general trend appeared across all sites, the degree of change differed depending on the land use. Natural and secondary forests showed a pronounced increase from the pre-monsoon to monsoon season, while plantations such as oil palm, teak and areca nut displayed more moderate seasonal shifts. Current jhum plots, on the other hand, exhibited the strongest contrasts among seasons.

Based on the particle size distribution analysis, soils of the Dampa Tiger Reserve were predominantly 'sand' in texture. The average bulk density (0-20cm) value ranged from 1.2 g/cm³ to 1.4 g/cm³. It is maximum in soil under the teak plantation and minimum under the natural forest. Soil under the natural forest had the maximum moisture content, followed by areca nut plantation, while soil under the teak plantation had the minimum recorded moisture content. Meanwhile, the oil palm plantation site, jhum cultivation, and the secondary forest exhibited soil moisture content ranging from 19.3% to 19.8%. The water holding capacity of soil also followed similar trend as the moisture content with maximum WHC recorded from the natural forest and minimum from the teak plantation site. The soils under the studied land use systems were found to be acidic in reaction with the mean pH values

recorded as low as 4.9 under the natural forest and as high as 5.3 under the teak plantation site. The average value of soil organic carbon was the highest under the natural forest (1.6%) and the lowest under the teak plantation site (0.9%). Similar pattern was observed for soil organic matter as well with the maximum SOM (2.8%) under natural forest and the minimum under the teak plantation (1.5%). The soil under the jhum cultivation had the highest available nitrogen content (242.8 kg/ha), followed by the natural forest (239.4 kg/ha) and the least available nitrogen content was observed under the teak plantation site (210.1 kg/ha). The natural forest exhibited the highest mean value of soil available phosphorus (12.5 kg/ha) while the lowest value (6.5 kg/ha) was observed under the arecanut plantation site. The soil available potassium was observed to be the highest in the jhum cultivation site (387.7 kg/ha) and lowest in the teak plantation site (382.4kg/ha). Soil chemical parameters varied significantly across the different land use systems, except for pH, which showed no significant variation.

PCA was conducted to extract indicators as minimum dataset for evaluating the SQI. Dimensionality reduction identified a key set of variables, narrowing the nine parameters to a minimum dataset comprising available P, SOC, and pH. SQI was calculated after transforming the variables in the MDS using linear scoring functions. The mean additive SQI at the overall soil depth was the highest under the natural forest (0.90) during the post-monsoon season, followed by the secondary forest (0.89), and the areca nut plantation (0.88). While majority of the land use systems recorded the maximum SQI during the post-monsoon season, the current jhum recorded its peak SQI (0.83) during the pre-monsoon season.

A total of 91 tree species belonging to 39 families were recorded from the natural forest in the core zone. *Schima wallichii* with an IVI value of 17.9 was the most dominant species, followed by *Mesua ferrea* (12.33), *Syzygium cumini* (11.93), *Macropanax undulatus* (10.61), and *Magnolia oblonga* (10.59). Combretaceae (FIVI= 24.15) was the most ecologically dominant family, followed by Lauraceae with an FIVI value of 21.4, Theaceae and Myrtaceae with an FIVI of 20.8 and 20.55 respectively. The secondary forest in the buffer zone exhibited lesser species diversity, represented by 67 tree species across 36 families. The top 5 highest IVI

values were recorded for *Gmelina arborea* (32.19), followed by *Schima wallichii* (20.22), *Macaranga indica* (16.25), *Callicarpa arborea* (16.22), and *Sterculia villosa* (15.58). Family-wise dominance analysis revealed that Lamiaceae with an FIVI value of 55.07 was the most dominant family, followed by Fabaceae (23.39), Malvaceae (22), and Theaceae (21.69). A total of 10 tree species are recorded from the current jhum site, *Schima wallichii* (IVI= 67.77) and *Albizia procera* (53.85) emerged as the most dominant trees in this site. Monoculture stands of oil palm and teak recorded 7 tree species while areca nut stand comprised of 9 species. Shannon-Weiner diversity index followed the following decreasing order- natural forest (4.15) > secondary forest (3.64) > current jhum (1.19) > oil palm (0.27) > teak (0.17) > areca nut (0.13). Basal cover was the highest in natural forest (51.28 m²/ha), followed by teak plantation (26.27 m²/ha), secondary forest (19 m²/ha), areca nut plantation (15.39 m²/ha), and current jhum (1.99 m²/ha). Natural and secondary forests yielded a log- normal dominance distribution curve, while the monoculture plantations yielded a geometric curve. The highest Sorensen similarity index was observed between the natural forest and secondary forest. Tree density and red listed status are important predictors of tree and species absence in the buffer zone of DTR.

34.22% of the total respondents claimed to have experienced problems with wildlife, mainly in the form of crop loss (70.57%), livestock depredation (8.11%), human casualties (15.32%), and property damage (6.01%). Wildlife induced crop damage showed clear seasonal and temporal variations influenced by specific animal species and crop types. Crops that are typically grown in shifting cultivation sites like rice and local vegetables were found to be strongly and positively associated with crop damage. Furthermore, the positive coefficients of crops such as bananas, oranges, pineapple, and oil palm suggested that households growing these crops were at higher risk of damage by wildlife. The survey revealed that chickens were the lone animals predated by smaller carnivores such as leopard cat, jackal and wild dogs. Two models from the model set were selected as the best fit model based on their $\Delta AICc$. The top models explained that free ranging chickens were more susceptible to predation by wild animals as evidenced by the positive coefficient.

6.14% of the total respondents claimed to have sustained injuries due to wild animals attack. Findings on human casualties revealed that snakes were responsible for the largest proportion of cases. Only 35.21% of those experiencing wildlife related damages reported to the authorities and seek for financial compensation. From the model set, three top models were identified explaining factors driving households' compensation claim. Village was associated with compensation claim, with people residing in West Phaileng village were more likely to report wildlife-related damages to the authorities and seek for ex gratia compensation. The multiple linear regression model identified factors influencing communities' perceptions towards wildlife conservation. Perception was found to improve significantly with higher levels of education, making education a key influencing factor. In addition, belonging to a particular village emerged an important factor shaping perception, with residents of Damparengpui village exhibiting a more positive perception towards wildlife conservation

The findings highlight that Dampa Tiger Reserve has undergone notable land use/land cover changes, primarily driven by anthropogenic pressures. These spatial changes have direct implications for habitat quality and human-wildlife conflict within the reserve. Microclimatic factors including air temperature, soil temperature, and relative humidity varied significantly across land use types. The natural forest stands inside the core zone of DTR maintained relatively cooler temperature and higher humidity across all seasons, while the modified land use systems, particularly the current jhum exhibited the hottest and driest conditions. The soil and air temperature exhibited a distinct seasonal pattern, opposite to that of relative humidity across all land use types. The thermal buffering capacity of forest was particularly evident during the pre-monsoon season owing to the greater canopy cover, species diversity, and higher structural complexity. Furthermore, the conversion of forests to alternate land use types has negative effects on soil properties. Soils under natural forest exhibited the highest quality among all land-use types, largely due to the diverse and abundant litter inputs characteristic of forest ecosystems. Conversely, soils under teak plantation were inferior in quality compared to oil palm, areca nut, jhumland, and forests. The study also identifies that among the soil parameters pH,

available phosphorus, and soil organic carbon as sensitive indicators playing a central role in determining the soil quality index (SQI) in the region. Across all land use systems, SQI peaked during the post-monsoon season, with the exception of the jhum cultivation site, which exhibited its highest SQI during the pre-monsoon season. Soil quality was consistently better in the surface soil as indicated by the higher SQI in the top soil across all land use systems. Additionally, depth-wise assessment showed that soil parameters at both 0–10cm and 10–20cm were responsive to land use changes. Overall, the soil of the study area is acidic in reaction which is typical of the soils in the hilly northeastern part of the country. The 123 tree species recorded from DTR highlights the richness of DTR in terms of biodiversity and underscores its importance as a species-rich ecological reservoir. The higher species richness, diversity, structural complexity, and ecological stability observed in the forest within core zone provide clear evidence of the negative impacts of land use modifications within the buffer zone. The core-zone forest was dominated by mid- to late-successional species, whereas the modified land cover types in the buffer zone were primarily composed of early- to mid-successional species. Red-list status, tree DBH, and stem density were identified as key predictors of individual tree absence in the buffer zone, whereas stem density alone significantly predicted species absence. The findings highlight the role of undisturbed forest in the core zone as an important species reservoir and a refuge for rare species and old growth-mature trees with large DBH. Habitat degradation resulting from land-use change has exacerbated human-wildlife conflict (HWC) in DTR. Local communities reported crop depredation as the major form of HWC with occasional livestock predation, human casualties, and property damage. Crop type emerged as a significant driver of wildlife induced crop damage with rice and other palatable crops particularly in jhum fields are the most susceptible to raiding. Wild boars and rodents were identified as the primary contributors to crop damage with additional impacts caused by primates, ungulates, and birds. Crop damage was most pronounced at night and during the monsoon season, coinciding with the period when crops reached maturity. Chicken were the only domestic animals predated by smaller carnivores including leopard cats, jackals, and wild dogs. Housing chicken in secure enclosures reduced the risk of predation. Snake bite was the most form of human casualties reported in the region,

while wild pigs and bears attack was also reported by few respondents. Reports of property damage were limited, with only a few respondents from Damparengpui village indicating such incidents. About one-third of respondents who experienced wildlife-induced damage reported the incidents to the authorities and filed for financial compensation. Proximity to the administrative office was a major factor influencing reporting behavior, with respondents living closer to the office showing a higher likelihood of reporting conflict incidents. Perceptions toward wildlife conservation were shaped by factors such as education level, age, and respondent's village. The findings of this study suggest that land-use alterations not only degrade ecological integrity but also increase the likelihood of human-wildlife conflict. Sustaining intact forest within the core zone is therefore crucial, as these areas play a key role in maintaining biodiversity, supporting soil quality, and stabilizing local microclimatic conditions. Ensuring sustainable land-use in the surrounding buffer zone is equally important, as responsible management practices, community engagement, and habitat-sensitive development can ease anthropogenic pressures and enhance overall ecosystem resilience.

RECOMMENDATIONS

Based on the findings of the study, the following are some recommendations to support effective conservation and sustainable practices and reduce human-wildlife conflict in Dampa tiger reserve, Mizoram:

1. Strengthen protection of core forest areas
 - Maintain strict protection of intact forest within the core zone, as these areas support high tree diversity, stable ecological conditions and wildlife.
 - Intensify patrolling and habitat monitoring to prevent illegal activities within the core zone and helps maintain habitat quality.
2. Promote sustainable land use practices in the buffer zone
 - Encourage agroforestry system in the buffer zone. Given that areca-nut plantations are already established in the buffer zone, promoting areca nut based agroforestry offers a practical alternative for sustainable land management. Integrating shade-tolerant crops such as pepper, banana, ginger, or turmeric into existing areca-nut stands can enhance soil health and improve household income.
 - Promote soil conservation techniques among local communities
 - Optimization of fallow periods to support nutrient recovery and promote natural regeneration of tree species.
 - Support alternatives livelihood including ecotourism, beekeeping, NTFP-based income to reduce pressure on forest.
3. Mitigate human-wildlife conflict
 - Ease of reporting incidents and simplifying compensation claims appear to be a key requirement of the region.
 - Considering the significant temporal variation in raiding, guarding of fields during high-risk seasons and peak activity periods should be encouraged. In the Indian context, even the wild pigs which are widely perceived as the most problematic animal are under rigid protection, making it essential to prioritize non-lethal management strategies. Practices that have been proven to be effective elsewhere such as using acoustic and visual repellents like fire

crackers, bon fire, tying colorful clothes on poles, loosely and closely hung glass bottles so as to produce sound, could be employed.

- Human casualties due to wild animals were mostly manifested in the form of snakebite. Raising awareness on preventive measures and snakebite management is particularly important in the region.
 - Conduct awareness programs on safe coexistence practices.
4. Encourage community participation in conservation and decision making
- Engage local communities and traditional institutions in decision-making, habitat restoration, and conflict management.
 - Provide training on sustainable resource use

APPENDICES

Appendix-A.

Human-Wildlife Conflict

(Assessment of nature of human-wildlife conflict, attitude and perception of people towards human-wildlife conflict)

Questionnaire Survey

Socio-Economic Background

- 1) Village: _____
- 2) Name of the respondent: _____
- 3) Age of the respondent: _____
- 4) Sex
☐ Male ☐ Female ☐ Third Gender
- 5) Community
☐ Bru ☐ Mizo ☐ Chakma ☐ Gorkhali ☐ Others
- 6) Marital Status
☐ Married ☐ Unmarried ☐ Widowed ☐ Separated
- 7) Educational Qualification
☐ No formal Education ☐ Primary level ☐ Middle School level
☐ High School level ☐ Graduation level ☐ Post-Graduate level
- 8) Occupation
☐ Farmer ☐ Government Employee ☐ Daily Wage ☐ Cattle rearing
☐ Self -Employed ☐ Business ☐ Unemployed
☐ Others (Specify)_____

9) Family annual income _____

10) Livestock owned

☐ Cows ☐ Poultry ☐ Pigs ☐ Goats ☐ Others (Specify)

11) Where do you keep your livestock?

☐ Livestock enclosure ☐ Backyard ☐ Roam freely

12) Why do you keep your livestock?

☐ Economic benefit ☐ Meat ☐ Milk ☐ Cultural value

☐ Others (Specify) _____

13) Do you practice farming?

☐ Yes ☐ No

14) If yes, what kind of farming do you practice?

☐ Shifting cultivation ☐ Permanent farming

15) How far is your cultivation site from the reserve?

16) How far is your cultivation site from the nearest water source?

17) What are the major crops grown?

18) Do you receive any kind of income/benefit from the reserve?

☐ Yes

☐ No

Nature and Extent of Conflict

1) Have you faced any problem with wild animals?

☐ Yes

☐ No

2) What kind of problem do you have with wild animals?

☐ Crop raiding ☐ Livestock depredation ☐ Human casualties

☐ Property damage ☐ Others (Specify) _____

3) In which season do animals raid your crop?

☐ Summer ☐ Winter ☐ Autumn ☐ Rainy

4) When do animals raid your crop?

☐ Morning ☐ Noon ☐ Evening ☐ Night

5) Which crop is most vulnerable to raiding?

☐ Paddy ☐ Maize ☐ Pumpkin ☐ Taro ☐ Banana ☐ Oil palm

☐ Others (Specify) _____

6) Which animals are involved in crop raiding?

Animals	√/×	Specify
Wild Boar		
Primates		
Ungulates		
Elephants		

Rodents		
Others		

7) When do animals raid your livestock?

☐ Dawn ☐ Morning ☐ Noon ☐ Evening ☐ Dusk ☐ Night

8) Which livestock is most vulnerable to wild animals attack?

☐ Cow ☐ Poultry ☐ Goats ☐ Pigs

9) Which animals are involved in livestock depredation?

Animals	√/×	Specify
Canids		
Felids		
Raptors		
Others		

10) Have you suffered any injury/casualty due to wild animal attack?

☐ Yes ☐ No

11) Which animal attacked you?

☐ Malayan sunbear ☐ Black bear ☐ Wild boar ☐ Elephant ☐

Snakes

☐ Others (Specify)_____

12) What were you doing when the animal attacked you?

☐ Working in field ☐ Collecting firewood ☐ Fetching water

☐ Collecting non-timber resource ☐ Hunting

☐ Others (Specify)_____

13) Which animals are involved in property damage?

☐ Elephant ☐ Bear ☐ Others (Specify)_____

14) How much is the estimated cost of loss due to crop raiding by wild animals
in the last two
years?_____

15) How much is the estimated cost of loss due to livestock depredation by wild
animals in the last two
years?_____

16) Did you claim for compensation for the loss?

☐ Yes ☐ No

17) If no, why?

18) If yes, amount claimed?

19) Amount received for compensation?

20) Do you receive the compensation on time?

☐ Yes ☐ No

21) Do you receive in full amount?

☐ Yes ☐ No

22) Are you satisfied with the amount of compensation received?

☐ Yes ☐ No

23) Do you notice any change in the LULC in and around the reserve in the past
years?

☐ Yes ☐ No

Attitudes & Perceptions

1) Protected areas are important/beneficial-

☐ Strongly Disagree ☐ Disagree ☐ Neither Agree Nor

Disagree

☐ Agree ☐ Strongly Agree

2) Wildlife Conservation is an appropriate use of land

☐ Strongly Disagree ☐ Disagree ☐ either Agree Nor Disagree

☐ Agree ☐ Strongly Agree

3) I am happy to see wild animals

☐ Strongly Disagree ☐ Disagree ☐ Neither Agree Nor

Disagree

☐ Agree ☐ Strongly Agree

4) All the animals including problematic animals require protection-

☐ Strongly Disagree ☐ Disagree ☐ Neither Agree Nor

Disagree

☐ Agree ☐ Strongly Agree

5) Wild Animals and people can live harmoniously-

☐ Strongly Disagree ☐ Disagree ☐ Neither Agree Nor

Disagree

☐ Agree ☐ Strongly Agree

6) I am happy to be living near/next to a protected area

☐ Strongly Disagree ☐ Disagree ☐ Neither Agree Nor

Disagree

☐ Agree ☐ Strongly Agree

7) What people need is more important than protecting wild animals

☐ Strongly Disagree ☐ Disagree ☐ Neither ☐ Agree ☐ Nor

Disagree

☐ Agree ☐ Strongly Agree

8) Protected areas are a waste of land in Mizoram

☐ Strongly Disagree ☐ Disagree ☐ Neither ☐ Agree ☐ Nor

Disagree

☐ Agree ☐ Strongly Agree

9) Animals should not be killed/harmed when they cause damage to the crops-

☐ Strongly Disagree ☐ Disagree ☐ Neither ☐ Agree ☐ Nor

Disagree

☐ Agree ☐ Strongly Agree

10) Animals should not be killed/harmed when they depredate livestock-

☐ Strongly Disagree ☐ Disagree ☐ Neither ☐ Agree ☐ Nor

Disagree

☐ Agree ☐ Strongly Agree

11) Animals should not be killed/harmed when they cause injury or loss of human lives-

☐ Strongly Disagree ☐ Disagree ☐ Neither ☐ Agree ☐ Nor

Disagree

☐ Agree

☐ Strongly Agree

12) Which animals are the most problematic species? Rank them

a) _____

b) _____

c) _____

13) Why do you think wild animals destroy crops?

14) Why do you think wild animals attack livestock?

15) Why do you think wild animals attack human?

Coping/Mitigation Strategies and Impacts on Wildlife

1. Do you guard your field against wild animals?

☐ Yes

☐ No

2. What preventive measures do you take to deter wild animals?

☐ Fencing

☐ Making loud noises

☐ Scarecrows

☐ Others

(Specify) _____

3. Which preventive measure is the most effective in your opinion?

Appendix-B. Summary of statistical tests for association between variables used for predicting crop loss, livestock predation, and compensation

Category	Variables Compared	Test Used	Test Statistics	df	p-value
Crop Loss	Dist. DTR & Dist. WS	Pearson's correlation	$r = 0.24$	–	<0.001
Crop Loss	Agriculture type & Crop	Cramer's V	$V = 0.96$	17	<0.001
Crop Loss	Agriculture type & Guarding	Cramer's V	$V = 0.43$	1	<0.001
Crop Loss	Agriculture type & Dist.DTR	Point– Biserial	$r = 0.027$	491	0.54
Crop Loss	Agriculture type & Dist. WS	Point– Biserial	$r = -0.074$	491	0.10
Crop Loss	Crops & Dist.DTR	Kruskal–Wallis	$X^2 = 35.06$	17	<0.001
Crop Loss	Crops & Dist. WS	Kruskal–Wallis	$X^2 = 28.25$	17	<0.001
Crop Loss	Guarding & Crops	Cramer's V	$V = 0.48$	17	<.001
Crop Loss	Guarding & Dist. DTR	Point– Biserial	$r = -0.12$	491	0.008
Crop Loss	Guarding & Dist. WS	Point– Biserial	$r = -0.09$	491	0.053
Predation	Village & Reason	Cramer's V	$V = 0.196$	3	<0.001
Predation	Village & WAK	Cramer's V	$V = 0.28$	6	<0.001
Predation	WAK & Reason	Cramer's V	$V = 0.093$	2	<0.001
Compensation	Village & CD	Cramer's V	$V = 0.337$	3	<0.001
Compensation	Village & AD	Cramer's V	$V = 0.287$	3	<0.001
Compensation	Village & Injury	Cramer's V	$V = 0.164$	3	0.05
Compensation	Village & PD	Cramer's V	$V = 0.289$	3	<0.001
Compensation	CD & AD	Cramer's V	$V = 0.65$	1	0
Compensation	CD & Injury	Cramer's V	$V = 0.415$	1	<0.001
Compensation	CD & PD	Cramer's V	$V = 0.415$	1	<0.001
Compensation	AD & PD	Cramer's V	$V = 0.078$	1	0.1
Compensation	AD & Injury	Cramer's V	$V = 0.06$	1	0.3
Compensation	PD & Injury	Cramer's V	$V = 0.05$	1	0.35
Compensation	Loss & Village	Kruskal-Wallis	$X^2 = 49.67$	3	<0.000
Compensation	Loss & CD	Kruskal-Wallis	$X^2 = 49.67$	1	0.04
Compensation	Loss & AD	Kruskal_Wallis	$X^2 = 5.27$	1	0.021
Compensation	Loss & PD	Kruskal_Wallis	$X^2 = 9.47$	1	0.002
Compensation	Loss & Injury	Kruskal_Wallis	$X^2 = 0.38$	1	0.534
Dist.DTR: Distance of farms from DTR, Dist.WS: Distance of the nearest water source to the farms, WAK: Where animals are kept, CD: Crop Damage, AD: Animals Depredation, PD: Property Damage					

Appendix-C. Summary of AICc based model selection from Generalized Linear Model explaining factors influencing predicted probability of wildlife induced crop loss in DTR.

Model	AICc	Delta_AICc	Weight
Distance_DTR + Crops + Guarding	401.4636	0.000000	0.711
Distance_DTR + Distance_WS + Crops + Guarding	403.3514	1.887769	0.277
Distance_WS + Crops + Guarding	410.6821	9.218523	0.007
Crops + Guarding	411.1795	9.715849	0.005
Distance_DTR + Crops	422.3797	20.916059	0.000
Distance_DTR + Distance_WS + Crops	424.4255	22.961856	0.000
Crops	428.0127	26.549055	0.000
Distance_WS + Crops	428.5463	27.082732	0.000
Distance_DTR + Guarding	587.4230	185.959399	0.000
Distance_DTR + Distance_WS + Guarding	589.3862	187.922610	0.000
Guarding	595.5407	194.077091	0.000
Distance_WS + Guarding	597.1361	195.672520	0.000
Distance_DTR	684.3994	282.935807	0.000
Distance_DTR+ Distance_WS	685.8738	284.410154	0.000
Distance_WS	687.4057	285.942070	0.000
Distance_DTR:Distance of farm from Dampa Tiger Reserve, Distance_WS: Distance of the farms to the nearest water source			

Appendix-D. Summary of AICc based model selection from Generalized Linear Model explaining factors influencing predicted probability domestic animals depredation by wildlife in DTR.

Model	AICc	Delta_AICc	Weight
WAK	92.94703	0.000000	0.57
WAK + Reason	94.23274	1.285715	0.30
Village + WAK	96.79003	3.843007	0.08
Village + WAK + Reason	98.18311	5.236085	0.04
Village	175.53667	82.589646	0.00
Village + Reason	176.29499	83.347961	0.00
Reason	187.69234	94.745308	0.00
WAK – Where animals are kept, Reason – Reason for keeping domestic animals			

Appendix-E. Summary of AICc based model selection from Generalized Linear Model explaining factors influencing predicted probability households' claim for compensation due to wildlife induced damages in DTR.

Model	AICc	Delta_AICc	Weight
Village + Loss	280.1898	0.0000000	0.333
Village + Loss + Injury	281.1254	0.9355407	0.208
Village + CD + Loss	282.1777	1.9878917	0.123
Village + PD + Loss	282.2825	2.0926141	0.117
Village + CD + Loss + Injury	283.1611	2.9712263	0.008
Village + PD + Loss + Injury	283.2325	3.0426536	0.072
Village + CD + PD + Loss	284.2896	4.0997134	0.042
Village + CD + PD + Loss + Injury	285.2876	5.0977736	0.026
Village + CD + Injury	305.2605	25.0706545	0.000
Village + CD	307.1608	26.9709088	0.000
Village + CD + PD + Injury	307.3468	27.1569371	0.000
Village + Injury	308.1370	27.9471571	0.000
Village + CD + PD	309.2378	29.0479085	0.000
Village + PD + Injury	310.2125	30.0226780	0.000
Loss	312.2306	32.0407452	0.000
Loss + Injury	313.2219	33.0320811	0.000
Village	313.5051	33.3152973	0.000
CD + Loss	313.7140	33.5241646	0.000
PD + Loss	313.7516	33.5617457	0.000
PD + Loss + Injury	314.7498	34.5599298	0.000
CD + Loss + Injury	314.7996	34.6097141	0.000
CD + PD + Loss	315.2963	35.1064097	0.000
Village + PD	315.5740	35.3841034	0.000
CD + PD + Loss + Injury	316.3869	36.1970801	0.000
Injury	341.4926	61.3027256	0.000
CD + Injury	342.6266	62.4367282	0.000
PD + Injury	343.0913	62.9014663	0.000
CD + PD + Injury	344.1166	63.9267372	0.000

CD	344.9942	64.8043814	0.000
CD + PD	346.4937	66.3038501	0.000
PD	348.2360	68.0461902	0.000
CD– Crop damage, AD– Animal depredation, PD– Property damage			

Appendix-F. Pairwise comparisons of air temperature among land use types using Dunn's post hoc test after Kruskal-Wallis analysis. P-values were adjusted with the Bonferroni method. Significant differences are indicated in bold.

Comparison	Z	P.unadj	P.adj
AN - CJ	0.33	0.741	1
AN - NF	3.76	0.00017	0.0026
CJ - NF	3.43	0.00061	0.0092
AN - OP	1.31	0.189	1
CJ - OP	0.98	0.326	1
NF - OP	-2.44	0.0145	0.218
AN - SF	2.44	0.0146	0.219
CJ - SF	2.11	0.0347	0.521
NF - SF	-1.32	0.188	1
OP - SF	1.13	0.259	1
AN - T	1.17	0.242	1
CJ - T	0.84	0.402	1
NF - T	-2.59	0.0097	0.145
OP - T	-0.14	0.886	1
SF - T	-1.27	0.203	1

AN- Areca nut, NF: Natural forest CJ: Current jhum, SF: Secondary forest, OP: Oil palm, T: Teak

Appendix-G. Pairwise seasonal difference in air temperature for Natural forest (NF), Secondary forest (SF), Teak (T), and Areca nut (AN) based on Kruskal-Wallis analysis followed by Dunn's post hoc test. P-values were adjusted with the Bonferroni method. Significant differences are indicated in bold.

Land Use	Season Comparison	Z	P.unadj	P.adj
NF	Monsoon – Post Monsoon	2.66	0.0078	0.0234
	Monsoon – Pre Monsoon	-0.54	0.5871	1
	Post Monsoon – Pre Monsoon	-3.2	0.0014	0.0041
SF	Monsoon – Post Monsoon	1.99	0.047	0.14
	Monsoon – Pre Monsoon	-1.99	0.047	0.14
	Post Monsoon – Pre Monsoon	-3.98	0.00007	< .001
T	Monsoon – Post Monsoon	2.29	0.022	0.067
	Monsoon – Pre Monsoon	-1.31	0.192	0.575
	Post Monsoon – Pre Monsoon	-3.59	0.0003	0.001
AN	Monsoon – Post Monsoon	1.42	0.156	0.469
	Monsoon – Pre Monsoon	-1.42	0.156	0.469
	Post Monsoon – Pre Monsoon	-2.84	0.005	0.014

Appendix-H. Pairwise seasonal difference in air temperature for Current jhum (CJ) and Oil palm (OP) based on Welch's ANOVA test followed by Games-Howell post hoc test.

Land Use	Season Comparison	Difference Estimate	95% CI Low	95% CI High	Adjusted P-value	Significance
CJ	Pre-monsoon–Monsoon	5.88	2	9.77	0.01	**
	Pre-monsoon–Post-monsoon	9.58	5.7	13.5	< .001	***
	Monsoon–Post-monsoon	3.7	1.96	5.44	0.002	**
OP	Pre-monsoon–Monsoon	2.13	3.74	8	0.515	ns
	Pre-monsoon–Post-monsoon	7.27	1.02	13.5	0.025	*
	Monsoon–Post-monsoon	5.13	0.8	9.46	0.026	*

Appendix-I. Pairwise comparisons of relative humidity among land use types using Dunn's post hoc test after Kruskal-Wallis analysis. P-values were adjusted with the Bonferroni method. Significant differences are indicated in bold.

Comparison	Z	P.unadj	P.adj
AN - CJ	1.17	0.244	1
AN - NF	-3.53	0.00041	0.0062
CJ - NF	-4.7	2.6E-06	< .001
AN - OP	-2.61	0.0091	0.136
CJ - OP	-3.77	0.00016	0.0024
NF - OP	0.92	0.356	1
AN - SF	-0.32	0.749	1
CJ - SF	-1.49	0.137	1
NF - SF	3.21	0.00132	0.0198
OP - SF	2.29	0.0221	0.332
AN - T	-0.47	0.641	1
CJ - T	-1.63	0.103	1
NF - T	3.06	0.00218	0.0327
OP - T	2.14	0.0322	0.483
SF - T	-0.15	0.884	1

AN- Areca nut, NF: Natural forest CJ: Current jhum, SF: Secondary forest, OP: Oil palm, T: Teak

Appendix-J. Pairwise seasonal difference in relative humidity for Natural forest (NF), Secondary forest (SF), Oil palm (OP), Teak (T), and Areca nut (AN) based on Kruskal-Wallis analysis followed by Dunn's post hoc test. P-values were adjusted with the Bonferroni method. Significant differences are indicated in bold.

Land use	Season Comparison	Z	Unadjusted p-value	Adjusted p-value
PF	Monsoon – Post-monsoon	1.96	0.0499	0.1497
	Monsoon – Pre-monsoon	3.92	0.00009	< .001
	Post-monsoon – Pre-monsoon	1.96	0.0499	0.1497
SF	Monsoon – Post-monsoon	2.42	0.015	0.046
	Monsoon – Pre-monsoon	3.46	0.001	0.002
	Post-monsoon – Pre-monsoon	1.03	0.301	0.902
OP	Monsoon – Post-monsoon	1.96	0.05	0.149
	Monsoon – Pre-monsoon	3.59	0.0003	0.001
	Post-monsoon – Pre-monsoon	1.63	0.103	0.309
T	Monsoon – Post-monsoon	1.95	0.051	0.153
	Monsoon – Pre-monsoon	3.91	0	< .001
	Post-monsoon – Pre-monsoon	1.95	0.051	0.153
AN	Monsoon – Post-monsoon	1.31	0.191	0.574
	Monsoon – Pre-monsoon	3.59	0.0003	0.001
	Post-monsoon – Pre-monsoon	2.29	0.022	0.067

Appendix-K. Pairwise seasonal difference in relative humidity for Current jhum (CJ) based on one-way ANOVA test followed by Tukey's post hoc test. Significant differences are indicated in bold.

Land use	Comparison	Difference	95% CI Lower	95% CI Upper	Adjusted p-value
CJ	Monsoon – Pre-monsoon	19	12.92	25.08	< .001
	Post-monsoon – Pre-monsoon	8.83	2.76	14.91	0.0049
	Monsoon – Post-monsoon	10.17	16.24	4.09	0.0016

Appendix-L. Tukey's HSD Post hoc test of mean soil temperature (overall depth) across different land use systems

Comparison	Mean Difference	Lower Bound	Upper Bound	Adjusted p-value
J – AN	1.89	-0.76	4.54	0.3192
OP – AN	-0.86	-3.51	1.79	0.9374
NF – AN	-3.41	-6.07	-0.76	0.0037
SF – AN	-0.11	-2.76	2.54	1
T – AN	-0.39	-3.04	2.26	0.9983
OP – J	-2.75	-5.4	-0.1	0.0373
NF – J	-5.3	-7.96	-2.65	< .001
SF – J	-2	-4.65	0.65	0.2572
T – J	-2.28	-4.93	0.38	0.1381
NF – OP	-2.55	-5.21	0.1	0.0669
SF – OP	0.75	-1.9	3.4	0.9649
T – OP	0.47	-2.18	3.13	0.9957
SF – NF	3.3	0.65	5.96	0.0056
T – NF	3.03	0.37	5.68	0.0152
T – SF	-0.28	-2.93	2.38	0.9997
Bold face indicates significant difference				
AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T:				

Appendix-M. Tukey's HSD Post hoc test of mean WHC (overall depth) across different land use systems

Comparison	Mean Difference	Lower Bound	Upper Bound	Adjusted p-value
J – AN	1.07	-1.73	3.86	0.8815
NF – AN	2.46	-0.33	5.26	0.1187
OP – AN	-2.22	-5.01	0.58	0.2074
SF – AN	-0.82	-3.62	1.97	0.9579
T – AN	-4.16	-6.96	-1.36	< .001
NF – J	1.4	-1.4	4.19	0.7047
OP – J	-3.28	-6.08	-0.49	0.0111
SF – J	-1.89	-4.69	0.9	0.3766
T – J	-5.23	-8.02	-2.43	< .001
OP – NF	-4.68	-7.48	-1.88	< .001
SF – NF	-3.29	-6.09	-0.49	0.0109
T – NF	-6.62	-9.42	-3.83	< .001
SF – OP	1.39	-1.41	4.19	0.7084
T – OP	-1.94	-4.74	0.85	0.3457
T – SF	-3.34	-6.13	-0.54	0.0093
Bold face indicates significant difference				
AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T:				

Appendix-N. Tukey's HSD Post hoc test of mean SOC (overall depth) across different land use systems

Comparison	Difference	Lower CI	Upper CI	Adjusted p-value
J-AN	0.2774	-0.0031	0.5578	0.0545
NF-AN	0.6167	0.3362	0.8972	< .001
OP-AN	0.041	-0.2395	0.3214	0.9983
SF-AN	-0.009	-0.2894	0.2715	0.9999
T-AN	-0.1191	-0.3996	0.1614	0.826
NF-J	0.3393	0.0589	0.6198	0.0079
OP-J	-0.2364	-0.5169	0.0441	0.1527
SF-J	-0.2863	-0.5668	-0.0059	0.0423
T-J	-0.3965	-0.6769	-0.116	< .001
OP-NF	-0.5757	-0.8562	-0.2953	< .001
SF-NF	-0.6257	-0.9061	-0.3452	< .001
T-NF	-0.7358	-1.0163	-0.4553	< .001
SF-OP	-0.0499	-0.3304	0.2305	0.9957
T-OP	-0.1601	-0.4405	0.1204	0.572
T-SF	-0.1101	-0.3906	0.1703	0.8686
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-O. Tukey's HSD Post hoc test of mean SOM (overall depth) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	0.4782	-0.0054	0.9617	0.0545
NF-AN	1.0632	0.5796	1.5467	< .001
OP-AN	0.0706	-0.4129	0.5542	0.9983
SF-AN	-0.0155	-0.499	0.4681	0.9999
T-AN	-0.2053	-0.6889	0.2782	0.826
NF-J	0.585	0.1015	1.0685	0.0079
OP-J	-0.4075	-0.8911	0.076	0.1527
SF-J	-0.4936	-0.9772	-0.0101	0.0423
T-J	-0.6835	-1.167	-0.2	< .001
OP-NF	-0.9925	-1.4761	-0.509	< .001
SF-NF	-1.0786	-1.5622	-0.5951	< .001
T-NF	-1.2685	-1.752	-0.785	< .001
SF-OP	-0.0861	-0.5696	0.3974	0.9957
T-OP	-0.276	-0.7595	0.2076	0.572
T-SF	-0.1899	-0.6734	0.2936	0.8686
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-P. Tukey's HSD Post hoc test of mean Available Nitrogen (overall depth) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	16.6858	6.3232	27.0484	< .001
NF-AN	13.2733	2.9107	23.6359	0.0039
OP-AN	0.0482	-10.3144	10.4108	1
SF-AN	-2.0873	-12.4499	8.2753	0.9923
T-AN	-15.784	-26.1466	-5.4214	< .001
NF-J	-3.4124	-13.7751	6.9502	0.9336
OP-J	-16.6376	-27.0002	-6.275	< .001
SF-J	-18.7731	-29.1357	-8.4105	< .001
T-J	-32.4698	-42.8324	-22.1072	< .001
OP-NF	-13.2251	-23.5877	-2.8625	0.0041
SF-NF	-15.3607	-25.7233	-4.9981	< .001
T-NF	-29.0573	-39.4199	-18.6947	< .001
SF-OP	-2.1356	-12.4982	8.2271	0.9914
T-OP	-15.8322	-26.1948	-5.4696	< .001
T-SF	-13.6967	-24.0593	-3.3341	0.0026
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-Q. Tukey's HSD Post hoc test of mean Available Phosphorus (overall depth) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	3.8507	1.6499	6.0514	< .001
NF-AN	5.9564	3.7557	8.1572	< .001
OP-AN	1.7315	-0.4693	3.9322	0.2141
SF-AN	1.186	-1.0148	3.3867	0.6323
T-AN	0.7947	-1.406	2.9955	0.9043
NF-J	2.1057	-0.095	4.3065	0.0696
OP-J	-2.1192	-4.32	0.0815	0.0665
SF-J	-2.6647	-4.8655	-0.464	0.0079
T-J	-3.056	-5.2567	-0.8552	0.0012
OP-NF	-4.225	-6.4257	-2.0242	< .001
SF-NF	-4.7705	-6.9712	-2.5697	< .001
T-NF	-5.1617	-7.3624	-2.961	< .001
SF-OP	-0.5455	-2.7462	1.6552	0.9802
T-OP	-0.9367	-3.1375	1.264	0.8246
T-SF	-0.3912	-2.592	1.8095	0.9957
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-R. Tukey's HSD Post hoc test of mean Available Potassium (overall depth) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	35.8621	22.693	49.0312	< .001
NF-AN	30.5575	17.3884	43.7266	< .001
OP-AN	-12.5562	-25.7253	0.613	0.0713
SF-AN	8.6809	-4.4882	21.85	0.4075
T-AN	-25.0588	-38.2279	-11.8897	< .001
NF-J	-5.3046	-18.4737	7.8645	0.8558
OP-J	-48.4183	-61.5874	-35.2492	< .001
SF-J	-27.1812	-40.3503	-14.0121	< .001
T-J	-60.9209	-74.09	-47.7518	< .001
OP-NF	-43.1137	-56.2828	-29.9446	< .001
SF-NF	-21.8766	-35.0457	-8.7075	< .001
T-NF	-55.6163	-68.7854	-42.4472	< .001
SF-OP	21.2371	8.0679	34.4062	< .001
T-OP	-12.5026	-25.6717	0.6665	0.0735
T-SF	-33.7397	-46.9088	-20.5706	< .001
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-S. Tukey's HSD Post hoc test of mean soil temperature (0 – 10cm) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	2.3333	-1.8677	6.5344	0.591
NF-AN	-3.6611	-7.8622	0.54	0.124
OP-AN	-0.7222	-4.9233	3.4789	0.996
SF-AN	-0.3889	-4.59	3.8122	0.999
T-AN	-0.4444	-4.6455	3.7566	0.999
NF-J	-5.9944	-10.1955	-1.7934	0.001
OP-J	-3.0556	-7.2566	1.1455	0.289
SF-J	-2.7222	-6.9233	1.4789	0.419
T-J	-2.7778	-6.9789	1.4233	0.395
OP-NF	2.9389	-1.2622	7.14	0.331
SF-NF	3.2722	-0.9289	7.4733	0.219
T-NF	3.2167	-0.9844	7.4177	0.236
SF-OP	0.3333	-3.8677	4.5344	0.999
T-OP	0.2778	-3.9233	4.4789	1
T-SF	-0.0556	-4.2566	4.1455	1
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-T. Tukey's HSD Post hoc test of mean WHC (0 – 10cm) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	1.3595	-2.7607	5.4798	0.929
NF-AN	4.6755	0.5552	8.7958	0.016
OP-AN	-2.268	-6.3883	1.8522	0.601
SF-AN	-0.9126	-5.0329	3.2077	0.987
T-AN	-4.0821	-8.2024	0.0382	0.053
NF-J	3.316	-0.8043	7.4362	0.188
OP-J	-3.6276	-7.7478	0.4927	0.117
SF-J	-2.2721	-6.3924	1.8481	0.599
T-J	-5.4416	-9.5619	-1.3214	0.002
OP-NF	-6.9435	-11.0638	-2.8232	< .001
SF-NF	-5.5881	-9.7084	-1.4678	0.002
T-NF	-8.7576	-12.8779	-4.6373	< .001
SF-OP	1.3554	-2.7648	5.4757	0.930
T-OP	-1.8141	-5.9343	2.3062	0.795
T-SF	-3.1695	-7.2898	0.9508	0.231
Bold face indicates significant difference				
AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-U. Tukey's HSD Post hoc test of mean SOC (0 – 10cm) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	0.3731	-0.018	0.7642	0.070
NF-AN	0.6836	0.2925	1.0747	< .001
OP-AN	0.0239	-0.3672	0.415	0.999
SF-AN	-0.0514	-0.4425	0.3397	0.998
T-AN	-0.1333	-0.5245	0.2578	0.920
NF-J	0.3105	-0.0806	0.7016	0.201
OP-J	-0.3492	-0.7403	0.0419	0.108
SF-J	-0.4245	-0.8156	-0.0333	0.025
T-J	-0.5064	-0.8975	-0.1153	0.003
OP-NF	-0.6597	-1.0508	-0.2686	< .001
SF-NF	-0.735	-1.1261	-0.3439	< .001
T-NF	-0.8169	-1.208	-0.4258	< .001
SF-OP	-0.0753	-0.4664	0.3158	0.993
T-OP	-0.1572	-0.5484	0.2339	0.851
T-SF	-0.082	-0.4731	0.3092	0.990
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-V. Tukey's HSD Post hoc test of mean SOM (0 – 10cm) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	0.6432	-0.0311	1.3175	0.070
NF-AN	1.1785	0.5042	1.8528	< .001
OP-AN	0.0412	-0.6331	0.7155	0.999
SF-AN	-0.0886	-0.7629	0.5857	0.998
T-AN	-0.2299	-0.9042	0.4444	0.920
NF-J	0.5353	-0.139	1.2096	0.201
OP-J	-0.602	-1.2763	0.0723	0.108
SF-J	-0.7318	-1.406	-0.0575	0.025
T-J	-0.8731	-1.5473	-0.1988	0.004
OP-NF	-1.1373	-1.8116	-0.463	< .001
SF-NF	-1.2671	-1.9414	-0.5928	< .001
T-NF	-1.4084	-2.0827	-0.7341	< .001
SF-OP	-0.1298	-0.8041	0.5445	0.993
T-OP	-0.2711	-0.9454	0.4032	0.851
T-SF	-0.1413	-0.8156	0.533	0.990
Bold face indicates significant difference				
AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil				

Appendix-W. Tukey's HSD Post hoc test of mean Available Nitrogen (0 – 10cm) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	18.433	6.861	30.005	< .001
NF-AN	15.823	4.251	27.395	0.002
OP-AN	4.602	-6.97	16.175	0.856
SF-AN	1.007	-10.565	12.579	0.999
T-AN	-15.192	-26.764	-3.62	0.003
NF-J	-2.61	-14.182	8.963	0.986
OP-J	-13.831	-25.403	-2.258	0.009
SF-J	-17.426	-28.998	-5.853	< .001
T-J	-33.625	-45.197	-22.053	< .001
OP-NF	-11.221	-22.793	0.351	0.0629
SF-NF	-14.816	-26.388	-3.244	0.004
T-NF	-31.015	-42.587	-19.443	< .001
SF-OP	-3.595	-15.167	7.977	0.9451
T-OP	-19.794	-31.367	-8.222	0.004
T-SF	-16.199	-27.771	-4.627	0.0013
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-X. Tukey's HSD Post hoc test of mean Available Phosphorus (0 – 10cm) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	4.794	1.851	7.737	< .001
NF-AN	7.421	4.477	10.364	< .001
OP-AN	2.425	-0.518	5.369	0.1683
SF-AN	1.308	-1.635	4.252	0.7893
T-AN	0.903	-2.04	3.847	0.9478
NF-J	2.627	-0.317	5.57	0.1086
OP-J	-2.369	-5.312	0.575	0.1889
SF-J	-3.486	-6.429	-0.542	0.0106
T-J	-3.891	-6.834	-0.948	0.0029
OP-NF	-4.995	-7.939	-2.052	< .001
SF-NF	-6.112	-9.056	-3.169	< .001
T-NF	-6.518	-9.461	-3.574	< .001
SF-OP	-1.117	-4.061	1.826	0.8793
T-OP	-1.522	-4.466	1.421	0.6637
T-SF	-0.405	-3.348	2.538	0.9986
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-Y. Tukey's HSD Post hoc test of mean Available Potassium (0 – 10cm) across different land use systems

Comparison	Difference (diff)	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J-AN	51.056	37.852	64.261	< .001
NF-AN	31.508	18.303	44.712	< .001
OP-AN	-12.024	-25.228	1.18	0.0959
SF-AN	9.348	-3.857	22.552	0.3186
T-AN	-29.472	-42.676	-16.268	< .001
NF-J	-19.549	-32.753	-6.344	0.0005
OP-J	-63.08	-76.285	-49.876	< .001
SF-J	-41.709	-54.913	-28.504	< .001
T-J	-80.528	-93.733	-67.324	< .001
OP-NF	-43.532	-56.736	-30.327	< .001
SF-NF	-22.16	-35.364	-8.956	< .001
T-NF	-60.98	-74.184	-47.775	< .001
SF-OP	21.372	8.168	34.576	0.0001
T-OP	-17.448	-30.652	-4.244	0.0029
T-SF	-38.82	-52.024	-25.615	< .001
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-Z. Tukey's HSD Post hoc test of mean soil temperature (10 –20cm) across different land use systems

Comparison	Mean Difference	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J - AN	1.444	-1.975	4.864	0.823
NF - AN	-3.167	-6.586	0.253	0.086
OP - AN	-1	-4.42	2.42	0.957
SF - AN	0.167	-3.253	3.586	1
T - AN	-0.333	-3.753	3.086	0.999
NF - J	-4.611	-8.031	-1.191	0.002
OP - J	-2.444	-5.864	0.975	0.308
SF - J	-1.278	-4.697	2.142	0.886
T - J	-1.778	-5.197	1.642	0.659
OP - NF	2.167	-1.253	5.586	0.445
SF - NF	3.333	-0.086	6.753	0.061
T - NF	2.833	-0.586	6.253	0.164
SF - OP	1.167	-2.253	4.586	0.92
T - OP	0.667	-2.753	4.086	0.993
T - SF	-0.5	-3.92	2.92	0.998
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-AA. Tukey's HSD Post hoc test of mean WHC (10 – 20cm) across different land use systems

Comparison	Mean Difference	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J - AN	0.777	-2.903	4.457	0.990
NF - AN	0.254	-3.426	3.934	1.000
OP - AN	-2.163	-5.843	1.517	0.530
SF - AN	-0.737	-4.417	2.943	0.992
T - AN	-4.238	-7.918	-0.558	0.014
NF - J	-0.523	-4.203	3.157	0.998
OP - J	-2.940	-6.620	0.740	0.196
SF - J	-1.514	-5.194	2.166	0.838
T - J	-5.015	-8.695	-1.335	0.002
OP - NF	-2.417	-6.097	1.263	0.404
SF - NF	-0.991	-4.671	2.689	0.970
T - NF	-4.492	-8.172	-0.812	0.008
SF - OP	1.426	-2.254	5.106	0.870
T - OP	-2.075	-5.755	1.605	0.576
T - SF	-3.501	-7.181	0.179	0.072
Bold face indicates significant difference				
AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-AB. Tukey's HSD Post hoc test of mean SOC (10 – 20cm) across different land use systems

Comparison	Mean Difference	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J - AN	0.182	-0.143	0.507	0.585
NF - AN	0.55	0.225	0.875	< .001
OP - AN	0.058	-0.267	0.383	0.995
SF - AN	0.033	-0.292	0.358	0.9997
T - AN	-0.105	-0.43	0.22	0.936
NF - J	0.368	0.043	0.693	0.017
OP - J	-0.124	-0.449	0.201	0.878
SF - J	-0.148	-0.473	0.177	0.771
T - J	-0.287	-0.612	0.039	0.117
OP - NF	-0.492	-0.817	-0.167	< .001
SF - NF	-0.516	-0.841	-0.191	< .001
T - NF	-0.655	-0.98	-0.33	< .001
SF - OP	-0.025	-0.35	0.3	0.9999
T - OP	-0.163	-0.488	0.162	0.693
T - SF	-0.138	-0.463	0.187	0.818
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-AC. Tukey's HSD Post hoc test of mean SOM (10 – 20cm) across different land use systems

Comparison	Mean Difference	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J - AN	0.313	-0.247	0.874	0.585
NF - AN	0.948	0.387	1.508	< .001
OP - AN	0.1	-0.46	0.66	0.995
SF - AN	0.058	-0.503	0.618	0.9997
T - AN	-0.181	-0.741	0.38	0.936
NF - J	0.635	0.074	1.195	0.017
OP - J	-0.213	-0.773	0.347	0.878
SF - J	-0.255	-0.816	0.305	0.771
T - J	-0.494	-1.054	0.066	0.117
OP - NF	-0.848	-1.408	-0.287	< .001
SF - NF	-0.89	-1.451	-0.33	< .001
T - NF	-1.129	-1.689	-0.568	< .001
SF - OP	-0.042	-0.603	0.518	0.9999
T - OP	-0.281	-0.841	0.279	0.693
T - SF	-0.238	-0.799	0.322	0.818
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-AD. Tukey's HSD Post hoc test of mean Available Nitrogen (10 – 20cm) across different land use systems

Comparison	Mean Difference	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J - AN	14.939	-0.117	29.995	0.053
NF - AN	10.724	-4.332	25.779	0.312
OP - AN	-4.506	-19.562	10.55	0.953
SF - AN	-5.182	-20.238	9.874	0.917
T - AN	-16.376	-31.432	-1.32	0.025
NF - J	-4.215	-19.271	10.841	0.965
OP - J	-19.444	-34.5	-4.389	0.004
SF - J	-20.12	-35.176	-5.065	0.002
T - J	-31.315	-46.371	-16.259	< .001
OP - NF	-15.229	-30.285	-0.173	0.046
SF - NF	-15.905	-30.961	-0.849	0.032
T - NF	-27.1	-42.155	-12.044	< .001
SF - OP	-0.676	-15.732	14.38	0.999
T - OP	-11.87	-26.926	3.186	0.208
T - SF	-11.194	-26.25	3.862	0.266
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-AE. Tukey's HSD Post hoc test of mean Available Phosphorus (10 – 20cm) across different land use systems

Comparison	Mean Difference	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J - AN	2.907	0.027	5.787	0.046
NF - AN	4.492	1.612	7.372	< .001
OP - AN	1.038	-1.843	3.918	0.901
SF - AN	1.064	-1.816	3.944	0.891
T - AN	0.686	-2.194	3.566	0.982
NF - J	1.585	-1.295	4.465	0.602
OP - J	-1.87	-4.75	1.01	0.417
SF - J	-1.844	-4.724	1.037	0.433
T - J	-2.221	-5.101	0.659	0.229
OP - NF	-3.455	-6.335	-0.574	0.009
SF - NF	-3.428	-6.309	-0.548	0.01
T - NF	-3.806	-6.686	-0.926	0.003
SF - OP	0.026	-2.854	2.906	1
T - OP	-0.351	-3.231	2.529	0.999
T - SF	-0.377	-3.258	2.503	0.999
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-AF. Tukey's HSD Post hoc test of mean Available Potassium (10 – 20cm) across different land use systems

Comparison	Mean Difference	Lower CI (lwr)	Upper CI (upr)	Adjusted p-value
J - AN	20.668	3.113	38.223	0.011
NF - AN	29.607	12.052	47.162	< .001
OP - AN	-13.088	-30.643	4.467	0.263
SF - AN	8.014	-9.541	25.569	0.77
T - AN	-20.646	-38.201	-3.09	0.011
NF - J	8.939	-8.616	26.495	0.678
OP - J	-33.756	-51.311	-16.201	< .001
SF - J	-12.654	-30.209	4.901	0.299
T - J	-41.313	-58.869	-23.758	< .001
OP - NF	-42.696	-60.251	-25.14	< .001
SF - NF	-21.593	-39.148	-4.038	0.007
T - NF	-50.253	-67.808	-32.698	< .001
SF - OP	21.102	3.547	38.657	0.009
T - OP	-7.557	-25.112	9.998	0.811
T - SF	-28.66	-46.215	-11.105	< .001
Bold face indicates significant difference AN: Areca nut; NF: Natural Forest; SF: Secondary Forest; J: Jhum; OP: Oil Palm; T: Teak				

Appendix-AG. Summary of one way ANOVA showing variations in soil parameter across seasons within the natural forest

Source of Variation	df	F	p-value
Soil temperature (°C)	2	48.67	< .001
Bulk density (g/cm ⁻³)	2	9.163	< .001
Moisture Content (%)	2	53.74	< .001
WHC (%)	2	9.613	< .001
pH	2	5.138	0.011
SOC (%)	2	5.727	0.007
SOM (%)	2	5.727	0.007
Available N (kg/ha)	2	3.891	0.030
Available P (kg/ha)	2	6.446	0.004
Available K (kg/ha)	2	6.753	0.003
Bold face indicates significant difference			

Appendix-AH. Tukey's HSD post hoc tests for seasonal differences in soil parameters within natural forest

Soil parameter	Comparison	Mean diff	95% CI lower	95% CI upper	p-value
Temperature	Post-mon – Mon	-4.34	-5.62	-3.06	< .001
	Pre-mon – Mon	0.24	-1.04	1.52	0.889
	Pre-mon – Post-mon	4.58	3.30	5.87	< .001
Bulk density (g/cm ³)	Post-mon – Mon	0.34	0.10	0.58	0.004
	Pre-mon – Mon	0.38	0.14	0.62	0.001
	Pre-mon – Post-mon	0.04	-0.20	0.28	0.923
Moisture Content (%)	Post-mon – Mon	-9.11	-12.57	-5.66	< .001
	Pre-mon – Mon	-14.43	-17.88	-10.97	< .001
	Pre-mon – Post-mon	-5.31	-8.77	-1.86	0.002
Water Holding Capacity (%)	Post-mon – Mon	-0.15	-4.86	4.55	0.996
	Pre-mon – Mon	-7.35	-12.06	-2.65	0.002
	Pre-mon – Post-mon	-7.20	-11.91	-2.50	0.002
pH	Post-mon – Mon	0.57	0.12	1.02	0.010
	Pre-mon – Mon	0.41	-0.04	0.85	0.082
	Pre-mon – Post-mon	-0.16	-0.61	0.29	0.650
SOC (%)	Post-mon – Mon	0.50	0.09	0.90	0.014
	Pre-mon – Mon	0.02	-0.38	0.43	0.988
	Pre-mon – Post-mon	-0.47	-0.88	-0.07	0.020
SOM (%)	Post-mon – Mon	0.86	0.16	1.56	0.014
	Pre-mon – Mon	0.04	-0.66	0.74	0.988
	Pre-mon – Post-mon	-0.82	-1.52	-0.11	0.020
Available N (kg/ha)	Post-mon – Mon	13.11	0.50	25.72	0.040
	Pre-mon – Mon	1.54	-11.06	14.15	0.952
	Pre-mon – Post-mon	-11.57	-24.17	1.04	0.077
Available P (kg/ha)	Post-mon – Mon	5.23	1.65	8.81	0.003
	Pre-mon – Mon	2.33	-1.25	5.91	0.262
	Pre-mon – Post-mon	-2.90	-6.48	0.68	0.131
Available K (kg/ha)	Post-mon – Mon	7.71	-4.24	19.66	0.267
	Pre-mon – Mon	-10.13	-22.08	1.82	0.110
	Pre-mon – Post-mon	-17.84	-29.79	-5.89	0.002

Appendix-AI. Summary of one way ANOVA showing variations in soil parameter across seasons within the secondary forest

Source of Variation	Df	F	p-value
Soil temperature (°C)	2	6.929	< .001
Bulk density (g/cm ⁻³)	2	5.465	0.008
Moisture Content (%)	2	21.29	< .001
WHC (%)	2	4.597	0.017
pH	2	3.294	0.049
SOC (%)	2	2.34	0.112
SOM (%)	2	2.34	0.112
Available N (kg/ha)	2	7.797	0.001
Available P (kg/ha)	2	12.51	< .001
Available K (kg/ha)	2	1.846	0.174
Bold face indicates significant difference			

Appendix-AJ. Tukey's HSD post hoc tests for seasonal differences in soil parameters within the secondary forest

Soil parameter	Comparison	Mean diff	95% CI lower	95% CI upper	p-value
Temperature	Post-mon – Mon	-3.42	-5.74	-1.09	0.003
	Pre-mon – Mon	3.75	1.42	6.08	0.001
	Pre-mon – Post-mon	7.17	4.84	9.49	< .001
Bulk density (g/cm ⁻³)	Post-mon – Mon	0.29	0.04	0.54	0.018
	Pre-mon – Mon	0.29	0.04	0.54	0.021
	Pre-mon – Post-mon	-0.01	-0.25	0.24	0.999
Moisture (%)	Post-mon – Mon	-5.96	-10.36	-1.55	0.006
	Pre-mon – Mon	-11.72	-16.13	-7.31	< .001
	Pre-mon – Post-mon	-5.76	-10.17	-1.36	0.008
WHC (%)	Post-mon – Mon	1.37	-2.66	5.41	0.684
	Pre-mon – Mon	-3.47	-7.50	0.57	0.104
	Pre-mon – Post-mon	-4.84	-8.87	-0.80	0.016
pH	Post-mon – Mon	0.29	-0.10	0.67	0.172
	Pre-mon – Mon	0.39	0.00	0.77	0.048
	Pre-mon – Post-mon	0.10	-0.29	0.48	0.806
N (kg/ha)	Post-mon – Mon	23.57	6.76	40.37	0.004
	Pre-mon – Mon	0.29	-16.52	17.09	0.999
	Pre-mon – Post-mon	-23.28	-40.08	-6.47	0.005
P (kg/ha)	Post-mon – Mon	2.43	-0.13	4.99	0.066
	Pre-mon – Mon	-2.79	-5.35	-0.23	0.030
	Pre-mon – Post-mon	-5.22	-7.78	-2.66	< .001

Appendix-AK. Summary of one way ANOVA showing variations in soil parameter across seasons within the jhum cultivation site

Source of Variation	df	F	p- value
Soil temperature (°C)	2	25.43	< .001
Bulk density (g/cm ⁻³)	2	12.16	< .001
Moisture Content (%)	2	85.55	< .001
WHC (%)	2	2.072	0.142
pH	2	3.93	0.02
SOC (%)	2	0.471	0.628
SOM (%)	2	0.471	0.628
Available N (kg/ha)	2	6.661	0.003
Available P (kg/ha)	2	2.07	0.142
Available K (kg/ha)	2	0.815	0.451
Bold face indicates significant difference			

Appendix-AL. Tukey's HSD post hoc tests for seasonal differences in soil parameters within jhum cultivation site

Soil parameter	Comparison	Mean diff	95% CI lower	95% CI upper	p-value
Temperature	Post-mon – Mon	-4.67	-8.71	-0.63	0.021
	Pre-mon – Mon	7.00	2.96	11.04	< .001
	Pre-mon – Post-mon	11.67	7.63	15.71	< .001
Bulk density	Post-mon – Mon	0.37	0.11	0.63	0.004
	Pre-mon – Mon	0.50	0.25	0.76	< .001
	Pre-mon – Post-mon	0.14	-0.12	0.40	0.404
Moisture (%)	Post-mon – Mon	-4.60	-7.63	-1.57	0.002
	Pre-mon – Mon	-15.72	-18.75	-12.68	
	Pre-mon – Post-mon	-11.11	-14.15	-8.08	< .001
pH	Post-mon – Mon	0.26	-0.21	0.74	0.377
	Pre-mon – Mon	0.55	0.07	1.03	0.022
	Pre-mon – Post-mon	0.28	-0.20	0.76	0.327
N (kg/ha)	Post-mon – Mon	4.09	-8.16	16.34	
	Pre-mon – Mon	17.42	5.17	29.67	0.004
	Pre-mon – Post-mon	13.33	1.08	25.58	0.031
Bold face indicates significant difference					

Appendix-AM. Summary of one way ANOVA showing variations in soil parameter across seasons within the oil palm plantation

Source of Variation	df	F	p- value
Soil temperature (°C)	2	14.05	< .001
Bulk density (g/cm ⁻³)	2	4.47	0.019
Moisture Content (%)	2	39.08	< .001
WHC (%)	2	3.351	0.053
pH	2	3.64	0.037
SOC (%)	2	2.839	0.072
SOM (%)	2	2.839	0.072
Available N (kg/ha)	2	2.695	0.082
Available P (kg/ha)	2	9.727	< .001
Available K (kg/ha)	2	18.51	< .001
Bold face indicates significant difference			

Appendix-AN. Tukey's HSD post hoc tests for seasonal differences in soil parameters within oil palm cultivation site

Soil parameter	Comparison	Mean diff	95% CI lower	95% CI upper	p-value
Temperature	Post-mon – Mon	-3.25	-5.85	-0.65	0.011
	Pre-mon – Mon	2.33	-0.26	4.93	0.085
	Pre-mon – Post-mon	5.58	2.99	8.18	< .001
Bulk density (g/cm ⁻³)	Post-mon – Mon	0.34	0.06	0.62	0.014
	Pre-mon – Mon	0.19	-0.09	0.48	0.226
	Pre-mon – Post-mon	-0.15	-0.43	0.13	0.407
Moisture (%)	Post-mon – Mon	-6.00	-10.39	-1.62	0.005
	Pre-mon – Mon	-15.64	-20.02	-11.26	< .001
	Pre-mon – Post-mon	-9.64	-14.02	-5.26	< .001
pH	Post-mon – Mon	0.37	-0.18	0.92	0.241
	Pre-mon – Mon	0.60	0.05	1.16	0.030
	Pre-mon – Post-mon	0.23	-0.32	0.78	0.564
P (kg/ha)	Post-mon – Mon	2.98	-0.21	6.17	0.071
	Pre-mon – Mon	-2.75	-5.94	0.44	0.102
	Pre-mon – Post-mon	-5.73	-8.93	-2.54	< .001
K (kg/ha)	Post-mon – Mon	-33.09	-47.85	-18.33	< .001
	Pre-mon – Mon	-30.08	-44.84	-15.32	< .001
	Pre-mon – Post-mon	3.01	-11.75	17.77	0.871

Bold face indicates significant difference

Appendix-AO. Summary of one way ANOVA showing variations in soil parameter across seasons within the teak plantation

Source of Variation	df	F	p- value
Soil temperature (°C)	2	30.89	< .001
Bulk density (g/cm ⁻³)	2	5.7	0.007
Moisture Content (%)	2	27.27	< .001
WHC (%)	2	4.276	0.022
pH	2	16.05	< .001
SOC (%)	2	3.991	0.028
SOM (%)	2	3.991	0.028
Available N (kg/ha)	2	12.67	< .001
Available P (kg/ha)	2	29.91	< .001
Available K (kg/ha)	2	7.599	.001
Bold face indicates significant difference			

Appendix-AP. Tukey's HSD post hoc tests for seasonal differences in soil parameters within teak plantation

Soil parameter	Comparison	Mean diff	95% CI lower	95% CI upper	p-value
Temperature	Post-mon – Mon	-3.42	-5.40	-1.44	< .001
	Pre-mon – Mon	2.92	0.94	4.90	0.003
	Pre-mon – Post-mon	6.33	4.35	8.31	< .001
Bulk density (g/cm ⁻³)	Post-mon – Mon	0.32	0.06	0.58	0.013
	Pre-mon – Mon	0.30	0.04	0.55	0.021
	Pre-mon – Post-mon	-0.02	-0.28	0.24	0.979
Moisture (%)	Post-mon – Mon	-3.37	-9.18	2.43	0.340
	Pre-mon – Mon	-16.53	-22.33	-10.72	< .001
	Pre-mon – Post-mon	-13.16	-18.96	-7.35	< .001
WHC (%)	Post-mon – Mon	4.67	0.54	8.80	0.024
	Pre-mon – Mon	0.97	-3.16	5.11	0.832
	Pre-mon – Post-mon	-3.69	-7.83	0.44	0.087
pH	Post-mon – Mon	0.61	0.33	0.89	< .001
	Pre-mon – Mon	0.12	-0.16	0.40	0.526
	Pre-mon – Post-mon	-0.49	-0.77	-0.21	< .001
SOC (%)	Post-mon – Mon	-0.17	-0.62	0.28	0.632
	Pre-mon – Mon	0.34	-0.11	0.79	0.168
	Pre-mon – Post-mon	0.51	0.06	0.96	0.024
SOM (%)	Post-mon – Mon	-0.29	-1.07	0.49	0.632
	Pre-mon – Mon	0.59	-0.19	1.37	0.168
	Pre-mon – Post-mon	0.88	0.10	1.66	0.024
N (kg/ha)	Post-mon – Mon	22.13	10.52	33.74	< .001
	Pre-mon – Mon	3.43	-8.18	15.04	0.751
	Pre-mon – Post-mon	-18.70	-30.31	-7.09	0.001
P (kg/ha)	Post-mon – Mon	1.17	-0.57	2.92	0.241
	Pre-mon – Mon	-3.82	-5.57	-2.07	< .001
	Pre-mon – Post-mon	-5.00	-6.74	-3.25	< .001
K (kg/ha)	Post-mon – Mon	-23.50	-38.83	-8.17	0.002
	Pre-mon – Mon	-17.27	-32.60	-1.95	0.024
	Pre-mon – Post-mon	6.23	-9.10	21.55	0.584

Appendix-AQ. Summary of one way ANOVA showing variations in soil parameter across seasons within the areca nut plantation

Source of Variation	df	F	p- value
Soil temperature (°C)	2	20.36	< .001
Bulk density (g/cm ⁻³)	2	10.49	0.007
Moisture Content (%)	2	38.38	< .001
WHC (%)	2	0.068	0.935
pH	2	0.509	0.606
SOC (%)	2	3.532	0.040
SOM (%)	2	3.532	0.040
Available N (kg/ha)	2	6.45	0.004
Available P (kg/ha)	2	23.43	< .001
Available K (kg/ha)	2	20.07	< .001
Bold face indicates significant difference			

Appendix-AR. Tukey's HSD post hoc tests for seasonal differences in soil parameters within areca nut plantation

Soil parameter	Comparison	Mean diff	95% CI lower	95% CI upper	p-value
Temperature	Post-mon – Mon	-3.42	-5.40	-1.44	< .001
	Pre-mon – Mon	2.92	0.94	4.90	0.003
	Pre-mon – Post-mon	6.33	4.35	8.31	< .001
Bulk density (g/cm ⁻³)	Post-mon – Mon	0.32	0.06	0.58	0.013
	Pre-mon – Mon	0.30	0.04	0.55	0.021
	Pre-mon – Post-mon	-0.02	-0.28	0.24	0.979
Moisture (%)	Post-mon – Mon	-3.37	-9.18	2.43	0.340
	Pre-mon – Mon	-16.53	-22.33	-10.72	< .001
	Pre-mon – Post-mon	-13.16	-18.96	-7.35	< .001
WHC (%)	Post-mon – Mon	4.67	0.54	8.80	0.024
	Pre-mon – Mon	0.97	-3.16	5.11	0.832
	Pre-mon – Post-mon	-3.69	-7.83	0.44	0.087
pH	Post-mon – Mon	0.61	0.33	0.89	< .001
	Pre-mon – Mon	0.12	-0.16	0.40	0.526
	Pre-mon – Post-mon	-0.49	-0.77	-0.21	< .001
SOC (%)	Post-mon – Mon	-0.17	-0.62	0.28	0.632
	Pre-mon – Mon	0.34	-0.11	0.79	0.168
	Pre-mon – Post-mon	0.51	0.06	0.96	0.024
SOM (%)	Post-mon – Mon	-0.29	-1.07	0.49	0.632
	Pre-mon – Mon	0.59	-0.19	1.37	0.168
	Pre-mon – Post-mon	0.88	0.10	1.66	0.024
N (kg/ha)	Post-mon – Mon	22.13	10.52	33.74	< .001
	Pre-mon – Mon	3.43	-8.18	15.04	0.751
	Pre-mon – Post-mon	-18.70	-30.31	-7.09	0.001
P (kg/ha)	Post-mon – Mon	1.17	-0.57	2.92	0.241
	Pre-mon – Mon	-3.82	-5.57	-2.07	< .001
	Pre-mon – Post-mon	-5.00	-6.74	-3.25	< .001
K (kg/ha)	Post-mon – Mon	-23.50	-38.83	-8.17	< .001
	Pre-mon – Mon	-17.27	-32.60	-1.95	< .001
	Pre-mon – Post-mon	6.23	-9.10	21.55	0.584

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BIO-DATA

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EDUCATIONAL QUALIFICATION

Examination	Year of passing	Subjects	Marks (%/CGPA)	Board/School/University
10 th or Equivalent	2012	English, Additional English, Mathematics, Science, Social Science, Health Education	80	Seven Set Higher Secondary School, Shillong, Meghalaya
12 th or Equivalent	2014	Biology, Physics, Chemistry, English, Alternative English	66.2	St. Edmund's College (Higher Secondary Section), Shillong, Meghalaya
Bachelor's Degree	2017	Environmental Science (Honours)	68.1	St. Edmund's College Shillong, Meghalaya
Master's Degree	2019	Ecology and Environmental Science	8.6	Pondicherry University
National Eligibility Test (NET)	2019	Environmental Science	Qualified	University Grant Commission (UGC)
National Eligibility Test (NET) JRF	2020	Environmental Science	Qualified	University Grant Commission (UGC)

PUBLICATION IN JOURNALS

- **C Lalruatkimi**, Khumanthem Babina Devi, Nistha Khanna and Om Prakash Tripathi (2025). Influence of Land Use Patterns on Microclimatic Variables in Dampa Tiger Reserve, Mizoram. *Indian Journal of Science and Technology* 18(44), 3515-3523.
- **C Lalruatkimi**, Khumanthem Babina Devi, Ahmed Abdallah Adam Mohamed , Ruth VL Tleipuii, Ashish Paul, Gyati Yam, K Semy and Om Prakash Tripathi (2025). Seasonal Variation in Soil Quality across Different Land Use Systems in Dampa Tiger Reserve, Mizoram, India. *Eurasian Soil Science*. 58(8).
- Khumanthem Babina Devi, **C Lalruatkimi**, Reetashree Bordoloi, Lal Thawmmawii, Nistha Khanna, B. P. Mishra, Om Prakash Tripathi (2026). Modelling of Soil Moisture Content Using Readily Available Soil Variables and Support Vector Regression along the Forest Fragment Gradients. *Journal of Soil Science and Plant Nutrition*.
- Khumanthem Babina Devi, **C Lalruatkimi**, Ahmed Abdallah Adam Mohamed , Lalthawmawii Khawlhing and Om Prakash Tripathi (2025). Tree species diversity and population dynamics along the forest fragment gradient in Langol Reserve Forest, Manipur. *Vegetos*
- Ruth VL Tleipuii, **C Lalruatkimi** and Irene Lalnipari Sellate (2021). Assessment of Drinking Water Quality from OpenSources, Mizoram, Northeast India. *Journal of Environment Pollution and Human Health* 10 (1), 23-30.
- **C Lalruatkimi**, S S Sundaravel, Lalawmawia Sailo, Betsy Zodinpuui and Hmar Lalthanzara (2019). Diversity and abundance of birds in Reiek Biodiversity Spot, Mizoram, northeastern India. *Science Vision* 19(4), 109-119.

CONFERENCE PRESENTATION

- Presented a paper (poster) entitled, “Seasonal Variation of Soil Organic Carbon in Dampa Tiger Reserve, Mizoram” at National Conference on Sustainable Solutions: Navigating Climate Change and Natural Resources, 19th – 20th June, 2024 at the Department of Environmental Science, Mizoram University.
- Presented a paper (oral) entitled, “Tree Species Species Diversity and Composition of Dampa Tiger, Mizoram” at Two days national seminar on Land Use and Bio-Resource Management for Sustainable Livelihood, 27th- 28th March, 2023.
- Presented a paper (oral) entitled, “Tree Species Diversity and Community Characteristics in Selected Forest Fragments in Kolasib, Mizoram” at 2nd International Conference on Biodiversity: Exploration, Exploitation and Conservation, Behali, Assam, February 2023.
- Presented a paper (oral) entitled, “Soil Properties under Selected Land Use Systems of Dampa Tiger Reserve, Mizoram” at 4th Mizoram Science Congress, 24th – 25th November, 2022.

WORKSHOP PARTICIPATION

Title/Academic Session/ Subject	Organizing Institution (with City and Country)	Period
One Day Workshop on Waste Composting and Organic Eco Gardening	Department of Environmental Science, Mizoram University	9 th March, 2023
Geoinformatics Hands on Training Workshop	Pachunga University College, Aizawl, Mizoram	23-27, May 2022
Ten-Day National Workshop on Mobile Campus-Based Training on basics of Remote Sensing and GIS	Department of Geography and Resource Management, , Mizoram University and Nirth-East Centre for Technology Application and Reach	16-21, September 2022

DECLARATION

I declare that the information provided above are true to the best of my knowledge and belief.

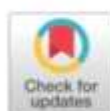
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Influence of Land Use Patterns on Microclimatic Variables in Dampa Tiger Reserve, Mizoram

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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 ($\rho = 0.82$, $P < 0.01$), whereas relative humidity was negatively correlated with air ($\rho = -0.45$, $P < 0.01$) and soil temperature ($\rho = -0.62$, $P < 0.01$). **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

DEGRADATION, REHABILITATION,
AND CONSERVATION OF SOILS

Seasonal Variation in Soil Quality across Different Land Use Systems
in Dampa Tiger Reserve, Mizoram, India

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Abstract—Soil quality is an essential element of ecosystem functionality and agricultural sustainability, and it varies among seasons and land use systems. Therefore, it is crucial to understand these variations for better soil health management and sustainable land use practices. The present study explores the seasonal variation in soil quality along the land use system in Dampa tiger reserve, Mizoram, Northeast India. Soil samples from two depths (0–10 and 10–20 cm) were collected in replicates from selected land use systems during pre, post-monsoon and monsoon seasons and brought to the laboratory for estimation of soil physico-chemical properties following standard methodologies. The additive and weighted methods were followed to determine the seasonal Soil Quality Index (SQI) involving selection of indicators as minimum data set, assigning scores to these indicators, and calculation of SQI. The analysis revealed significant effects of both land use and season on soil moisture content, water holding capacity, pH, soil organic carbon (SOC), soil organic matter, available potassium and available nitrogen at $p < 0.05$. SOC, pH, and available phosphorus constituted the minimum data set for estimation of SQI. Among the seasons, the post-monsoon was found to be the best for soil quality in all the land use systems except for traditional “jhum” cultivation site. The SQI was also found to decline when forests are converted into monoculture plantation of teak and oil palm. This study emphasizes the importance of understanding the seasonal variation and land use system impacts on soil quality, providing a framework for policymakers for assessing and improving soil conditions for long-term ecological and economic stability.

Keywords: soil quality index, minimum data set, soil parameters, land use systems

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INTRODUCTION

Soil is an important, life-sustaining natural resource that is not renewable at a human time scale. It consists of biotic, organic, and inorganic components along with water and gases. It serves as a physical basis for food production, socio-economic structures, and their development, along with various ecological, social, and economic functions [10, 19, 29]. Some of the major services provided by soil include cycling of nutrients, regulation of climate and water, retention and control of pollutants, provision of habitat for the rich biodiversity and acting as a reservoir for genetic diversity [56, 60, 62]. These ecosystem services highlight the crucial role of soil in sustaining environmental balance and underscore the importance of assessing soil quality. Several

attempts have been made to define soil quality; Doran and Parkin [19] defined it as “the ability of soil to function within the limits of ecosystem to promote biological productivity, preserve environmental quality, and support plant and animal health”.

Various indicators are available to assess the quality of soil, and these are a combination of soil biological, physical, and chemical properties that are sensitive to change in soil conditions [12, 42]. It is not possible to measure soil quality based on a single soil characteristic nor is it feasible to consider every soil property for assessing soil quality [40]. Thus, Soil Quality Index (SQI) involving selection of a minimum data set (MDS) to generate a numeric value, is the most accepted and widely used method in determining soil quality. In such assessment, MDS is generally constructed using methods such as Principal Component Analysis (PCA), fac-



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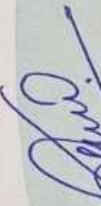


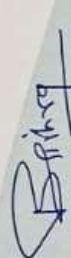
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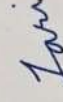
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In the Two Days National Seminar on *Land Use and Bioresource Management for Sustainable Livelihood*, Jointly organized by Department of Environmental Science, Mizoram University, Mizoram Science, Technology & Innovation Council (MISTIC) & National Bank for Agriculture & Rural Development (NABARD) on 27th-28th March, 2023 held at SES & NRM, Mizoram University.


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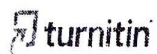
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DEPARTMENT	:	Environmental Science
TITLE OF THESIS	:	Assessment of tree diversity, habitat characteristics and human-wildlife conflict in Dampa Tiger Reserve, Mizoram
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Extension (If Any)	:	NIL

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Department of Environmental Science

ABSTRACT

ASSESSMENT OF TREE DIVERSITY, HABITAT CHARACTERISTICS AND HUMAN-WILDLIFE CONFLICT IN DAMPA TIGER RESERVE, MIZORAM

**AN ABSTRACT SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF
PHILOSOPHY**

C LALRUATKIMI

MZU REGISTRATION NO.: 2100080

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**DEPARTMENT OF ENVIRONMENTAL SCIENCE
SCHOOL OF EARTH SCIENCES AND NATURAL RESOURCES
MANAGEMENT
DECEMBER, 2025**

**ASSESSMENT OF TREE DIVERSITY, HABITAT CHARACTERISTICS
AND HUMAN-WILDLIFE CONFLICT IN DAMPA TIGER RESERVE,
MIZORAM**

**BY
C LALRUATKIMI
DEPARTMENT OF ENVIRONMENTAL SCIENCE**

**Prof. O.P. TRIPATHI
Supervisor
Department of Environmental Science**

**Submitted
In partial fulfillment of the requirement of the Degree of Doctor of Philosophy
in Environmental Science of Mizoram University, Aizawl**

ABSTRACT

In an effort to counter the declining rate of biodiversity and protect ecosystem structure, functions and services, several protected areas are established across the globe. The effectiveness and potential of a protected area to an extent is a function of the surrounding landscape. Several protected areas are threatened by increased human pressure in various forms such as land use change, pollution, invasive species, hunting and other threats. The loss of protected area functionality and integrity due to changes in the surrounding landscapes not only weakens biodiversity conservation and ecosystem services but also alters the movement pattern of wildlife. Dampa Tiger Reserve (DTR) constitutes the largest protected area in Mizoram, and is home to a rich diversity of flora and fauna. However, like many protected areas in India, the surrounding landscapes of DTR are experiencing extreme anthropogenic pressures from land use change, expansion of human settlements, and habitat fragmentation. Such disturbances not only threaten ecosystem sustainability and habitat suitability, but also modify vegetation composition and structure, thereby influencing tree diversity, habitat characteristics, and escalating human-wildlife conflict in and around the reserve.

Given the growing human pressures around the reserve and their ecological consequences, this study seeks to understand how land use changes affect tree diversity, habitat characteristics, and the pattern and occurrence of human-wildlife conflict in DTR. In line with this aim, the study was designed with the following specific objectives:

1. To assess the spatio-temporal extent of land use/land cover changes in Dampa Tiger Reserve.
2. To study the microclimate, soil characteristics, tree diversity and community characteristics in the different land use types of Dampa Tiger Reserve.
3. To evaluate perceptions and attitudes of people regarding human-wildlife conflict, and identify the drivers for mitigation measures.

Land Use/Land Cover (LULC) classification was conducted using the Google Earth Engine (GEE) platform, utilizing Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) Surface Reflectance data for the dry season periods (February–April) of 2011 and 2021, respectively. Change analysis was performed and LULC maps of the year 2011 and 2021 were generated. Based on remotely-sensed data and ground validation, six major land use systems were further selected for the assessment of microclimate, soil characteristics, and tree diversity and community characteristics. They are natural forest (NF), secondary forest (SF), current jhum (CJ), Oil palm (OP), Teak, and Areca nut (AN) plantations. To understand the microclimate, ambient temperature and relative humidity was determined using Thermo Hygrometer. Soil samples were collected from two different depths (0–10 cm and 10–20 cm) randomly from each site considering three seasons namely pre-monsoon (January – April), monsoon (May – August), and post-monsoon (September – December) seasons. The collected soil samples were analysed to determine various physic and chemical properties including moisture content, bulk density, water-holding capacity, pH, organic carbon, organic matter, available nitrogen, phosphorus and potassium following standard methodologies. For phyto-sociological analysis, sampling was conducted in the core and buffer zone of the DTR. For field sampling, several 20m × 20m quadrats were laid in each zone following standard quadrat method keeping the physiographic conditions in account (Curtis and McIntosh 1950). Quantitative characters of the forest community such as spatial distribution, stand density, basal cover, and importance value index (IVI) were calculated following Misra (1968), Mueller-Dombois & Ellenberg (1974) and Magurran (1988). To assess the nature and extent of human-wildlife conflicts and identify factors driving these conflicts, and to assess people's perception on wildlife conservation, four fringe villages located in the buffer zone of Dampa Tiger Reserve were selected namely Damparengpui, Tuipuibari, West Phaileng, and Phuldungsei.

The analysis of land use land cover (LULC) change between 2011 and 2021 in DTR revealed notable shifts in land cover distribution. The spatial distribution of change between the two selected years showed that most of the land use changes are concentrated within the buffer zone of the reserve, where anthropogenic activity

seems to be highest. Forest continued to be the dominant land cover in both the year 2011 and 2021, however a decline in forest cover was observed, decreasing from 752 sq. km in 2011 to 737 sq. km in 2021. In contrast, the rest of the land use categories such as jhumland/barren, built-up areas, and water bodies exhibited an increasing trend over the decade.

The highest mean air temperature was recorded from the current jhum cultivation site (29.2°C), followed by monoculture plantation of areca nut (29.1°C) and teak (28.2°C). The oil palm plantation (27.5°C) and secondary forest (26.2°C) exhibited intermediate value while the lowest value was recorded in the primary forest (24.1°C). The Kruskal-Wallis rank sum test revealed significant air temperature variation across land use systems at $p < 0.05$. The recorded mean air temperature showed significant seasonal variation within each land use system. Under each land use system, the maximum value was recorded in the pre-monsoon season, followed by monsoon and post-monsoon season. This general pattern was consistent for both the forest sites and the more intensively used landscapes, although the degree of change was not uniform. The current jhum showed the greatest seasonal variation in temperature, whereas the natural forest exhibited the least variation, highlighting the temperature buffering capacity of natural forests. The Kruskal-Wallis rank sum test revealed significant relative humidity variation across land use systems at $p < 0.001$. The mean relative humidity was maximum in the natural forest (75.2%), followed by oil palm plantation (65.4%), teak and secondary forest with a value of 59.8%, areca nut (59.1%), and current jhum (54.8%). Across the different land-use systems, clear seasonal patterns in relative humidity was observed, with values peaked during the monsoon period and dropped again afterwards ($p < 0.001$). Although this general trend appeared across all sites, the degree of change differed depending on the land use. Natural and secondary forests showed a pronounced increase from the pre-monsoon to monsoon season, while plantations such as oil palm, teak and areca nut displayed more moderate seasonal shifts. Current jhum plots, on the other hand, exhibited the strongest contrasts among seasons.

Based on the particle size distribution analysis, soils of the Dampa Tiger Reserve were predominantly sand in texture. The average bulk density (0 – 20 cm) value ranged from 1.2 g/cm³ to 1.4 g/cm³. It is maximum in soil under the teak plantation and minimum under the natural forest. Soil under the natural forest (20.6%) had the maximum moisture content, followed by areca nut plantation (20.3%), while soil under the teak plantation (17.0%) had the minimum recorded moisture content. Meanwhile, the oil palm plantation site, jhum cultivation, and the secondary forest exhibited soil moisture content ranging from 19.3% to 19.8%. The water holding capacity of soil also followed similar trend as the moisture content with maximum WHC recorded from the natural forest (36.9%) and minimum from the teak plantation site (30.3%). The soils under the studied land use systems were found to be acidic in reaction with the mean pH values recorded as low as 4.9 under the natural forest and as high as 5.3 under the teak plantation site. The average value of soil organic carbon was the highest under the natural forest (1.6%), followed by the current jhum site (1.29%), and the lowest under was recorded in the teak plantation site (0.9%). Similar pattern was observed for soil organic matter as well, with the maximum SOM (2.8%) under natural forest and the minimum under the teak plantation (1.5%). The soil under the jhum cultivation had the highest available nitrogen content (242.8 kg/ha), followed by the natural forest (239.4 kg/ha) and the least available nitrogen content was observed under the teak plantation site (210.1 kg/ha). The natural forest exhibited the highest mean value of soil available phosphorus (12.5 kg/ha) while the lowest value (6.5 kg/ha) was observed under the arecanut plantation site. The soil available potassium was observed to be the highest in the jhum cultivation site (387.7 kg/ha) and lowest in the teak plantation site (382.4kg/ha). Soil chemical parameters varied significantly the different land use systems, except for pH, which showed no significant variation ($p < 0.05$).

Significant positive correlation was observed between temperature and SOC and SOM, whereas temperature was found to have negative correlation with moisture content, water holding capacity, and phosphorus. Bulk density was negatively correlated with moisture content, SOC, SOM, and available potassium. Significant positive relationship was observed between WHC and SOC, SOM, and

available nitrogen, phosphorus, and potassium. A strong significant positive relationship was observed between SOC and SOM. In addition SOC and SOM were found to have a significant relationship with available N, P, and K. The measured available macronutrients (N, P, and K) exhibited significant positive correlation among themselves.

PCA was conducted to extract indicators as minimum dataset (MDS) for evaluating the SQI. Dimensionality reduction identified a key set of variables, narrowing the nine parameters to a minimum dataset comprising available P, SOC, and pH. SQI was calculated after transforming the variables in the MDS using linear scoring functions. The mean additive SQI at the overall soil depth was the highest under the natural forest (0.90) during the post-monsoon season, followed by the secondary forest (0.89), and the areca nut plantation (0.88). While majority of the land use systems recorded the maximum SQI during the post-monsoon season, the current recorded its peak SQI (0.83) during the pre-monsoon season.

A total of 91 tree species belonging to 39 families were recorded from the natural forest in the core zone. *Schima wallichii* with an IVI value of 17.9 was the most dominant species, followed by *Mesua ferrea* (12.33), *Syzygium cumini* (11.93), *Macropanax undulatus* (10.61), and *Magnolia oblonga* (10.59). Combretaceae (FIVI= 24.15) was the most ecologically dominant family, followed by Lauraceae with an FIVI value of 21.4, Theaceae and Myrtaceae with an FIVI of 20.8 and 20.55 respectively. The secondary forest in the buffer zone exhibited lesser species diversity, represented by 67 tree species across 36 families. The top 5 highest IVI values were recorded for *Gmelina arborea* (32.19), followed by *Schima wallichii* (20.22), *Macaranga indica* (16.25), *Callicarpa arborea* (16.22), and *Sterculia villosa* (15.58). Family-wise dominance analysis revealed that Lamiaceae with an FIVI value of 55.07 was the most dominant family, followed by Fabaceae (23.39), Malvaceae (22), and Theaceae (21.69). A total of 10 tree species are recorded from the current jhum site, *Schima wallichii* (IVI= 67.77) and *Albizia procera* (53.85) emerged as the most dominant trees in this site. Monoculture stands of oil palm and teak recorded 7 tree species while areca nut stand comprised of 9 species. Shannon-Weiner diversity index followed the following decreasing order- natural forest (4.15) > secondary forest (3.64) > current jhum (1.19) > oil palm (0.27) > teak (0.17) >

areca nut (0.13). Simpson dominance index values were higher in the plantation sites compared to the natural and secondary forests. In contrast, an opposite pattern was observed for Pielou's evenness index values. Basal cover was the highest in natural forest (51.28 m²/ha), followed by teak plantation (26.27 m²/ha), secondary forest (19 m²/ha), areca nut plantation (15.39 m²/ha), and current jhum (1.99 m²/ha). Stand density was the highest in the areca nut plantation (1086 ind./ha), while it was the lowest in the current jhum (54 ind./ha). Natural and secondary forests yielded a log-normal dominance distribution curve, while the monoculture plantations yielded a geometric curve. The highest Sorensen similarity index was observed between the natural forest and secondary forest. Linear regression analysis revealed a significant but weak relationship between basal area and species richness ($R^2=0.18$), basal area and tree density ($R^2=0.24$). Whereas significant moderate relationship was observed between species richness and tree density ($R^2=0.57$). Tree density and red listed status are important predictors of tree and species absence in the buffer zone of DTR.

Of the total respondents, 34.22% claimed to have experienced problems with wildlife, mainly in the form of crop loss (70.57%), livestock depredation (8.11%), human casualties (15.32%) and property damage (6.01%). Wildlife induced crop damage showed clear seasonal and temporal variations influenced by specific animal species and crop types. Majority of crop raiding incidents occurred during the monsoon season and were concentrated during nocturnal hours. Wild boars and rodents were the primary crop raiding animals. Crops that are typically grown in shifting cultivation sites like rice and local vegetables were found to be strongly and positively associated with crop damage. Furthermore, the positive coefficients of crops such as bananas, oranges, pineapple, and oil palm suggested that households growing these crops were at higher risk of damage by wildlife. Distance of farms from the reserve as well as implementation of guarding emerged among the factors influencing crop damage in the region. The survey revealed that chickens were the lone animals predated by smaller carnivores such as leopard cat, jackal and wild dogs. The survey also revealed that chickens were the lone animals predated by these carnivores. Two models from the model set were selected as the best fit model based on their $\Delta AICc$. The top models explained that free ranging chickens were most

susceptible to predation by wild animals as evidenced by the positive coefficient. 6.14% of the total respondents claimed to have sustained injuries due to wild animals attack. Findings on human casualties revealed that snakes were responsible for the largest proportion of cases. Only 35.21% of those experiencing wildlife related damages reported to the authorities and seek for financial compensation. From the model set, three top models were identified explaining factors driving households' compensation claim. Village was associated with compensation claim, with people residing in West Phaileng village were more likely to report wildlife-related damages to the authorities and seek for financial compensation. The multiple linear regression model identified factors influencing communities' perceptions towards wildlife conservation. Perception was found to improve significantly with higher levels of education, making education a key influencing factor. In addition, belonging to a particular village emerged an important factor shaping perception, with residents of Damparengpui village exhibiting a more positive perception towards wildlife conservation

The findings of this study suggest that land-use alterations not only degrade ecological integrity but also increases the likelihood of human-wildlife conflict. Sustaining intact forest within the core zone is therefore crucial, as these areas play a key role in maintaining biodiversity, supporting soil quality, and stabilizing local microclimatic conditions. Ensuring sustainable land-use in the surrounding buffer zone is equally important, as responsible management practices, community engagement, and habitat-sensitive development can ease anthropogenic pressures and enhance overall ecosystem resilience.