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Diversity and Distribution of Native and Invasive Plant Species in the Highland Ecosystems of Tupi, South Cotabato, Philippines: Implications for Conservation and Management

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ABSTRACT

This study assessed the diversity and distribution of native and invasive plant species in the highland ecosystems of Tupi, South Cotabato, particularly in the barangays of Acmonan, Linan, and Kablon. Using a quantitative descriptive-comparative research design, vegetation data were collected through field surveys employing quadrat and transect sampling methods. Species were identified and classified as native or invasive, and biodiversity was evaluated using species richness, abundance, frequency, Importance Value Index (IVI), Shannon-Wiener Diversity Index, and species evenness. A total of 65 plant species were recorded, consisting of 32 native species (49%) and 33 invasive species (51%), indicating that the ecosystem is in a transitional state with invasive species slightly dominating. Critical invasive species such as Chromolaena odorata, Mikania micrantha, and Ageratum conyzoides were identified as major threats to native biodiversity. Among the study sites, Kablon exhibited the highest biodiversity (H′ = 2.37) and native species composition, while Acmonan showed the highest invasive species dominance. Results further revealed that native species abundance increased with elevation, whereas invasive species abundance decreased. The findings highlight the need for immediate conservation efforts, invasive species management, and habitat restoration to protect native biodiversity and maintain ecological stability in the highland ecosystems of Tupi, South Cotabato.

Keywords: *biodiversity, native species, invasive species, plant diversity, highland ecosystems, Tupi, South Cotabato.*

INTRODUCTION

Biodiversity plays a crucial role in maintaining ecological balance and ensuring ecosystem stability. Plant species diversity supports essential ecological functions such as soil protection, nutrient cycling, climate regulation, and providing habitats for wildlife. Diverse plant communities also enhance ecosystem resilience and productivity, allowing ecosystems to better adapt to environmental changes and disturbances (Díaz et al., 2021; Isbell et al., 2022). Because plants form the foundation of terrestrial ecosystems, understanding their diversity is important for effective conservation and sustainable environmental management.

However, biodiversity is increasingly threatened by the spread of invasive plant species. Invasive plants are non-native species that establish and spread rapidly in new environments, often competing aggressively with native species for resources such as sunlight, water, nutrients, and space. Their presence can disrupt ecological processes, alter habitat structure, and reduce native plant diversity in affected ecosystems (Seebens et al., 2021; Essl et al., 2023). As a result, biological invasions have become a significant environmental concern worldwide, posing serious risks to the integrity and sustainability of natural ecosystems across the globe.

Internationally, global assessments have documented thousands of plant species now recognized as invasive across multiple continents. These invasive species alter ecosystem processes, outcompete native flora, and contribute significantly to biodiversity loss on a global scale (Pyšek et al., 2022). International bodies such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) have identified biological invasions as one of the five leading direct drivers of biodiversity decline worldwide, urging nations to strengthen monitoring and management efforts in vulnerable ecosystems (Essl et al., 2023).

At the national level, the Philippines, recognized as one of the world's biodiversity hotspots, harbors a high number of endemic plant species across its diverse ecosystems. Nevertheless, the country faces a growing threat from invasive plant species, which have been documented in forests, grasslands, wetlands, and agricultural landscapes. The Department of Environment and Natural Resources–Biodiversity Management Bureau (DENR-BMB, 2021) has identified the proliferation of invasive species as a key driver of biodiversity loss in the Philippines, necessitating urgent monitoring, assessment, and management interventions across the country's natural landscapes.

Locally, the municipality of Tupi in South Cotabato, situated near Mount Matutum, contains highland ecosystems that support diverse vegetation and provide important ecological services in the region. Activities such as agricultural expansion, tourism development, and human settlement may contribute to the introduction and spread of invasive plants in these areas, potentially threatening native biodiversity (Shackleton et al., 2023). Despite the ecological importance of Tupi's highland ecosystems, limited local studies have documented the diversity and distribution of native and invasive plant species in the area.

In view of the foregoing, this study aims to assess the diversity of native and invasive plant species in selected highland ecosystems of Tupi, South Cotabato. Understanding the composition of plant communities and identifying invasive species are essential for developing effective conservation strategies and management plans, with the findings expected to contribute to biodiversity conservation and sustainable ecosystem management in the region (Pyšek et al., 2022).

Literature Review

Biodiversity and Ecosystem Stability

Biodiversity is widely recognized as a key component of ecosystem functioning because it influences processes such as nutrient cycling, productivity, and food web stability. Díaz (2021) explained that plant species diversity contributes significantly to soil fertility, water retention, and carbon sequestration in ecosystems. Additionally, Brondizio (2021) described how ecosystems with higher biodiversity tend to be more stable and capable of maintaining ecological balance. Diverse plant communities allow ecosystems to continue functioning even when environmental disturbances occur. Therefore, biodiversity plays a critical role in sustaining long-term ecosystem stability.

Recent studies also highlight the role of biodiversity in strengthening ecosystem resilience. Isbell (2022) found that ecosystems with greater plant species richness show stronger resistance to drought and climate variability. Likewise, Tilman (2022) demonstrated that higher biodiversity helps maintain stable primary productivity and efficient nutrient cycling. These ecological advantages demonstrate why biodiversity is essential for ecosystem health. As a result, protecting plant diversity has become a major focus of ecological research and conservation efforts.

Despite its ecological importance, biodiversity continues to decline globally due to increasing human activities. Seebens (2021) identified habitat destruction and land-use change as major drivers of biodiversity loss. Blackburn (2021) also argued that invasive species contribute significantly to the decline of native plant communities. These pressures reduce plant diversity and weaken ecosystem stability in many regions. Consequently, biodiversity conservation has become a critical environmental priority worldwide.

Functional diversity also plays an important role in ecosystem resilience. Liang (2023) explained that functional diversity refers to the variety of ecological roles performed by species within an ecosystem. Meanwhile, Crowther (2023) revealed that ecosystems with greater functional diversity are better able to maintain ecological functions during environmental disturbances. This diversity allows some species to compensate for others when conditions change. Maintaining both species diversity and functional diversity is therefore essential for ecosystem sustainability.

Climate change further intensifies threats to biodiversity worldwide. Bellard (2022) reported that changes in temperature and precipitation patterns can alter species distribution and habitat suitability. In addition, Jeschke (2022) discussed how climate change may increase the vulnerability of upland ecosystems where species depend on specific environmental conditions. These changes can weaken ecosystem resilience and threaten native plant communities. Therefore, biodiversity conservation must also consider climate-related environmental changes.

Biodiversity Assessment and Conservation Planning

Biodiversity assessment is essential for understanding ecosystem health and guiding conservation strategies. Cardinale (2021) stated that measuring species richness and diversity provides important baseline data for ecological monitoring. In addition, Duffy (2021) explained that diversity indices such as the Shannon-Wiener Index help researchers evaluate community structure and ecosystem stability. These tools allow scientists to compare biodiversity across ecosystems and identify priority conservation areas. Accurate biodiversity assessments therefore support effective environmental management.

Global conservation initiatives also highlight the importance of biodiversity monitoring. Díaz (2021) identified climate change and land-use change as major drivers of biodiversity loss worldwide. Furthermore, Brondizio (2021) discussed how monitoring biodiversity helps detect early signs of ecosystem degradation. Continuous ecological monitoring allows researchers to evaluate conservation interventions and environmental policies. These strategies are essential for preventing further biodiversity decline.

In the Philippines, biodiversity assessments provide valuable insights for ecosystem conservation. Manalo (2021) reported that vegetation surveys help identify priority areas for habitat restoration and environmental protection. Moreover, Alcantara (2021) noted that biodiversity inventories help detect invasive species that threaten native plant communities. Understanding plant distribution patterns allows environmental managers to develop targeted conservation strategies. As a result, biodiversity assessments play an important role in environmental planning.

Monitoring biodiversity also supports adaptive ecosystem management. Shackleton (2023) explained that tracking species diversity helps identify ecological hotspots and areas vulnerable to environmental disturbance. Likewise, Richardson (2023) pointed out that integrating scientific data with community knowledge improves conservation planning. This collaborative approach strengthens environmental management strategies. Consequently, biodiversity monitoring contributes to sustainable ecosystem conservation.

Despite advances in biodiversity research, ecological studies in upland municipalities remain limited. Manalo (2021) observed that many biodiversity studies focus primarily on lowland forests and protected areas. Alcantara (2021) further indicated that highland ecosystems in municipalities such as Tupi remain understudied. The lack of localized ecological data limits the development of effective conservation strategies. Therefore, further biodiversity research is needed in upland ecosystems.

Highland Ecosystems and Environmental Pressure

Highland ecosystems provide important ecological services such as watershed protection, soil stabilization, and climate regulation. Nguyen (2022) explained that plant communities in upland ecosystems

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are strongly influenced by elevation, microclimate, and soil characteristics. Le (2022) further described how these ecosystems often contain unique and endemic plant species adapted to cooler environmental conditions. These characteristics make highland ecosystems biologically important and ecologically sensitive. Protecting these ecosystems is therefore essential for maintaining regional biodiversity.

In the Philippines, upland ecosystems remain less studied compared to lowland forests. Manalo (2021) stated that many highland areas contain plant species with narrow ecological ranges and specialized habitat requirements. Alcantara (2021) added that these species are highly vulnerable to environmental disturbances. Because of their limited distribution, small environmental changes can greatly affect their survival. Understanding plant diversity in upland ecosystems is therefore important for conservation planning.

Human activities are major drivers of environmental pressure in highland ecosystems. Shackleton (2023) reported that agricultural expansion and land conversion contribute to habitat fragmentation in upland landscapes. Richardson (2023) further found that disturbances caused by logging and settlement development reduce plant species diversity. These environmental pressures weaken ecosystem resilience and increase the vulnerability of native plant communities. As a result, sustainable land management practices are necessary in upland ecosystems.

Climate change also poses additional threats to highland biodiversity. Bellard (2022) observed that rising temperatures may shift plant species distribution toward higher elevations. Moreover, Jeschke (2022) explained that changes in rainfall patterns can alter habitat suitability for many plant species. These environmental changes may increase the vulnerability of highland ecosystems to invasive species. Therefore, climate change adaptation strategies are essential for protecting upland biodiversity.

Highland ecosystems also provide important benefits to local communities. Díaz (2021) discussed how upland ecosystems contribute to water regulation and soil fertility. Brondizio (2021) additionally highlighted that these ecosystems support agricultural productivity and provide natural resources for rural communities. The degradation of upland ecosystems may therefore affect both ecological stability and human livelihoods. Protecting highland ecosystems is important for both environmental sustainability and community well-being.

Invasive Plant Species and Their Ecological Impacts

Invasive species are recognized as one of the leading drivers of biodiversity loss worldwide. Mack (2022) reported that invasive plants disrupt ecological interactions and reduce species richness in natural ecosystems. Gurevitch (2022) also described how biological invasions can significantly alter ecosystem processes such as nutrient cycling. These ecological changes may weaken ecosystem stability and resilience. As a result, invasive species management is an important component of biodiversity conservation.

Invasive species are recognized as one of the leading drivers of biodiversity loss worldwide. Simberloff (2022) reported that invasive plants disrupt ecological interactions and reduce species richness in natural ecosystems. Vitousek (2022) also described how biological invasions can significantly alter ecosystem processes such as nutrient cycling. These ecological changes may weaken ecosystem stability and resilience. As a result, invasive species management is an important component of biodiversity conservation.

In Southeast Asia, disturbed landscapes are particularly vulnerable to invasive plant establishment. Shackleton (2023) explained that areas near agricultural lands and roads provide ideal conditions for invasive plant colonization. Richardson (2023) additionally observed that environmental disturbances create opportunities for non-native species to spread rapidly. Once established, invasive plants may dominate plant communities and suppress native vegetation. This process threatens biodiversity in upland ecosystems.

Climate change may further accelerate the spread of invasive plant species. Bellard (2022) found that warming temperatures may allow invasive plants to expand into previously unsuitable environments.

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Jeschke (2022) further explained that environmental changes may favor the adaptability of invasive species compared to native plants. These changes can increase ecological pressure on native plant communities. Therefore, climate change may intensify the impacts of biological invasions.

Despite growing research on invasive species, local ecological studies remain limited in many upland areas. Manalo (2021) noted that the distribution of invasive plants in upland municipalities remains poorly documented. Alcantara (2021) concluded that understanding invasive plant impacts is essential for developing effective management strategies. Local studies are needed to identify invasive species and evaluate their ecological effects. Such research is important for protecting native biodiversity in upland ecosystems.

Native Plant Species and Ecological Importance

Native plant species are naturally occurring plants that have evolved within a particular region and developed ecological relationships with local organisms over time. According to Díaz et al. (2021), native plants contribute significantly to ecosystem functioning by supporting nutrient cycling, soil stability, and habitat availability for wildlife. Brondizio et al. (2021) also described how native vegetation helps maintain ecological balance and strengthens biodiversity conservation efforts. These ecological roles make native plant species essential components of healthy ecosystems.

Several studies have shown that ecosystems dominated by native plant species tend to demonstrate greater ecological resilience than ecosystems heavily influenced by non-native vegetation. Isbell et al. (2022) found that higher native species diversity improves ecosystem resistance to environmental stress and climate variability. Tilman et al. (2022) reported that native plant communities support stable primary productivity and efficient nutrient cycling. Beyond this, Liang et al. (2023) observed that diverse native vegetation enhances ecological interactions that sustain biodiversity and ecosystem productivity.

Research conducted in tropical and upland ecosystems further highlights the ecological importance of native plant diversity. Liang et al. (2023) discussed that native vegetation contributes to forest regeneration and improves soil conservation in mountainous environments. Crowther et al. (2023) noted that ecosystems with diverse native species are better able to maintain ecological functions during environmental disturbances. On the other hand, Shackleton et al. (2023) explained that native plant communities also provide habitat and food sources for pollinators and other wildlife species. These ecological functions are essential for maintaining ecosystem health and stability.

Despite their ecological importance, native plant communities continue to face increasing environmental pressures. Seebens et al. (2021) identified land-use change and habitat destruction as major causes of declining native plant diversity. Blackburn et al. (2021) reported that invasive alien species compete with native vegetation for resources such as sunlight, nutrients, and water. At the same time, Bellard et al. (2022) explained that climate change may intensify these threats by altering habitat suitability and species distribution. These disturbances reduce native species richness and weaken ecosystem resilience.

Although native plants are important for biodiversity conservation, ecological studies focusing on their diversity and distribution in upland municipalities remain limited. Manalo et al. (2021) noted that many biodiversity studies in the Philippines concentrate mainly on lowland forests and protected areas. Alcantara et al. (2021) observed that upland ecosystems in municipalities such as Tupi remain understudied despite their ecological significance. To address this gap, David Richardson et al. (2023) emphasized that localized ecological studies are essential for understanding plant community composition and supporting effective biodiversity conservation strategies.

Research Objectives

Assess the diversity and distribution of native and invasive plant species in the highland ecosystems of Tupi and determine their implications for conservation and management.

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Specific Objectives

1. Identify plant species and classify each as native or invasive.
2. Determine invasive plant species and assess their threat to native biodiversity.
3. Measure species richness, abundance, and frequency to describe plant community structure.
4. Evaluate biodiversity using the Shannon-Wiener Diversity Index.
5. Compare abundance and distribution of native and invasive species across sites and elevations.
6. Propose conservation strategies and management practices for ecosystem sustainability.

Conceptual Framework

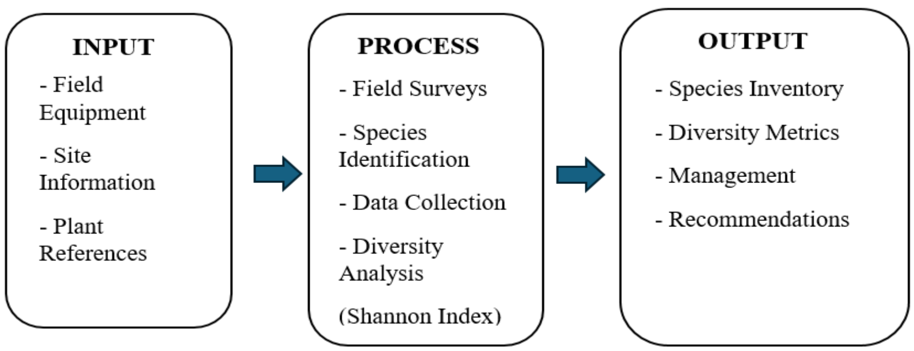

Figure 1. *IPO Conceptual Framework*

The conceptual framework depicts the Input-Process-Output (IPO) model guiding this study on the diversity and distribution of native and invasive plant species in the highland ecosystems of Tupi (Creswell & Creswell, 2021; Duffy, 2021). Inputs include essential resources such as field equipment, study site information, plant reference materials, and the research team. The process involves systematic field surveys, species identification, data collection, calculation of Shannon-Wiener diversity indices, and statistical analysis (Mueller-Dombois & Ellenberg, 2021; Suresh & Chandran, 2023). The outputs generated from these activities include comprehensive species inventories, quantitative diversity measures, spatial distribution maps, and evidence-based conservation and management recommendations (Brondizio et al., 2021; Department of Environment and Natural Resources – Biodiversity Management Bureau, 2021).

Theoretical Framework

The theoretical foundation of this study is anchored in the Theory of Biological Invasions, which explains how non-native species establish, spread, and impact native ecosystems. According to this theory, invasive plant species often possess ecological traits such as rapid growth, high reproductive capacity, and strong competitive ability that enable them to outcompete and displace native vegetation, thereby altering community composition and ecosystem processes (Seebens & Blackburn, 2021; Gaertner et al., 2021). In the context of highland ecosystems like Tupi, these mechanisms help explain variations in species richness and the dominance patterns observed between native and invasive plants.

Complementing this, the Biodiversity–Ecosystem Function (BEF) Framework posits that ecosystems with greater biodiversity tend to exhibit higher levels of productivity, resilience, and stability. Empirical studies demonstrate that diverse plant communities support key ecological functions including nutrient cycling, soil formation, and resistance to environmental stress and that reductions in biodiversity can weaken ecosystem resilience (Wagg & Allan, 2022; Dietrich & Loreau, 2024). This perspective is essential for interpreting how differences in native and invasive plant diversity may influence ecosystem integrity and ecological services in Tupi's highland areas.

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Together, these theoretical perspectives guide the investigation of how plant diversity and distribution patterns relate to ecological outcomes. The Theory of Biological Invasions frames expectations about the effects of invasive species on native communities, while the BEF Framework supports assessment of how plant diversity influences ecosystem stability and functionality. Grounding the study in these theories provides a basis for understanding species interactions, biodiversity patterns, and conservation implications in highland ecosystems.

METHODS

Research Design

This study employed a quantitative descriptive–comparative research design to assess and compare the diversity and distribution of native and invasive plant species in selected highland ecosystems of Tupi. Quantitative descriptive research was appropriate because it provided systematic documentation and quantification of observable ecological variables, including species richness and abundance (Creswell & Creswell, 2021). The comparative component enabled statistical analysis of differences between native and invasive plant communities in terms of diversity indices and spatial distribution (Suresh & Chandran, 2023). By integrating descriptive and comparative elements, the study was able to produce both accurate ecological profiles and meaningful comparisons of plant community structure. The research used a field-based ecological survey method to gather primary data on plant species composition and distribution. Ecological surveys were widely used in plant ecology to document vegetation patterns and quantify biodiversity in natural environments (Mueller-Dombois & Ellenberg, 2021). This method allowed for systematic observation and recording of both native and invasive species across different highland habitats, providing reliable data for diversity and distribution analysis.

Research Instrument

This study utilized field-based ecological survey instruments to collect primary data on the diversity and distribution of native and invasive plant species in Tupi's highland ecosystems. The main instruments included quadrats and transect lines, which allowed for systematic sampling of vegetation to assess species richness, abundance, and distribution patterns. Quadrats of fixed dimensions were randomly placed within selected highland sites to capture representative vegetation types, while transect lines connected quadrats and covered environmental gradients to study spatial distribution. Field guides and botanical references were used to accurately identify and classify each species as native or invasive, ensuring alignment with local flora records.

Additionally, a GPS detector was employed to record the precise location of each quadrat and transect, facilitating mapping of species distribution and spatial analysis. Standardized data sheets were used to record species counts, coverage, and relevant observations, which were later analyzed quantitatively using diversity indices such as the Shannon–Wiener Index. The combination of these instruments ensured systematic, replicable, and accurate data collection to support robust assessment of plant community structure in the highland ecosystems.

Study Site Selection

The study was conducted in the highland ecosystems of Tupi, South Cotabato, particularly in areas along the slopes and foothills of Mount Matutum, which rises to approximately 2,286 m above sea level and supports diverse vegetation communities (based on GPS summit coordinates 6.4333° N, 125.1083° E). To ensure representative sampling of the ecological conditions in highland environments, site selection considered primarily elevation (approximately 600 m and higher), vegetation type, and level of human disturbance, as plant composition and distribution often change along altitudinal gradients.

Sampling sites were established in Barangays Kablon, Acmonan, and Linan, all located near the slopes of Mount Matutum. Kablon sits at 647.8 m above sea level, serving as the primary highland site. Acmonan, with an average elevation of 514.5 m, offers transitional habitats extending close to 600 m. Linan, at approximately 367.2 m, represents mid-elevation areas rising toward the mountain slopes. Together, these locations provide a varied elevation gradient ideal for ecological assessment.

Selected vegetation types included relatively undisturbed forest edges, agroforestry areas, and grassland or open habitats to allow comparison between native and invasive plant species across different habitat structures and successional stages. In addition, sites were categorized according to the degree of human disturbance, ranging from minimally disturbed or protected forest areas to moderately and highly disturbed zones affected by agricultural expansion, settlement, or land conversion. Considering elevation, vegetation type, and anthropogenic pressures enabled the study to examine how these factors influenced the diversity and distribution of native and invasive plant species in Tupi's highland ecosystems.

Sampling Procedure

The study employed a purposive sampling method in selecting research sites within the highland ecosystems of Tupi. Sampling sites included Barangay Kablon, Acmonan, and Linan, chosen based on elevation (approximately 600 m and higher), vegetation type, level of human disturbance, and accessibility, to ensure representative coverage of Tupi's highland ecosystems along the slopes of Mount Matutum. These barangays provided a combination of undisturbed forest patches, secondary growth forests, agroforestry areas, and open grasslands, which met the study criteria for analyzing the diversity and distribution of native and invasive plant species.

Within each site, we used systematic random sampling to set up plots. We laid transect lines and placed quadrats at equal distances to keep the method consistent. We used different sizes for different plants: 1 m × 1 m for small herbs, 5 m × 5 m for shrubs, and 10 m × 10 m for trees. Using different sizes is necessary because plants vary in size and spread, so matching the quadrat size to the plant type gives more accurate results (Stohlgren, 1995). This method allowed us to properly measure and compare plant diversity in all layers of vegetation.

Vegetation Sampling

Plant species within each selected sampling site were identified and documented through quadrat and transect methods. The scientific names and taxonomic classification of all recorded species were verified using Co's Digital Flora of the Philippines, a continuously updated online checklist of Philippine vascular plants that provided information on taxonomy, distribution, and ecological status such as native, endemic, naturalized, or invasive species (Co's Digital Flora of the Philippines; Pelser et al., 2011 present). This database was regularly updated with recent taxonomic literature and expert contributions, making it a reliable reference for plant identification in the Philippines.

To further confirm plant nomenclature and classification, additional verification was conducted using Plants of the World Online, maintained by the Royal Botanic Gardens, Kew, which provided an authoritative and up-to-date global database of plant taxonomy and distribution (Royal Botanic Gardens& Kew, 2024). For records of invasive and introduced species occurring in the Philippines, the Global Register of Introduced and Invasive Species was also consulted to ensure accurate classification of invasive plant taxa (Pagad et al., 2022).

Furthermore, the conservation status of the documented plant species was assessed using the IUCN Red List of Threatened Species, which provided internationally recognized evaluations of species' extinction risk and conservation status (IUCN, 2023). These authoritative and updated references ensured accurate identification, classification, and conservation assessment of both native and invasive plant species documented in the highland ecosystems of Tupi, South Cotabato.

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Data Gathering Procedure

The data gathering procedure involved systematic fieldwork to document plant diversity in the highland ecosystems of Tupi, South Cotabato. Permission was secured from local authorities to access the selected barangays of Kablon, Acmonan, and Linan. These areas are located above 600 meters elevation and represent varying levels of human disturbance. A preliminary site visit was conducted to identify suitable locations and familiarize the researchers with the terrain. Transect lines and quadrats of varying sizes were established and placed at regular intervals. All plants were observed, identified, counted, and recorded in data sheets for proper documentation.

To ensure accuracy, all identifications underwent strict validation and cross-verification processes. Voucher specimens were collected, labeled, and described according to their specific habitat characteristics. Expert verification was conducted in consultation with taxonomists and DENR – Region XII officers. They reviewed the field notes, photographs, and actual specimens collected from the study sites. Species names were further cross-checked against authoritative databases to confirm scientific names and status. This process ensured that every identification was precise and followed standard botanical nomenclature.

Each species was classified as native or invasive based on published literature and reliable database records. The validated list was organized in tables showing scientific names, families, voucher numbers, and habitat types. All compiled data were prepared for statistical analysis to determine richness, abundance, and diversity indices. The analysis covered the different sampling sites and habitat types found within the highland areas. This approach ensured consistent, accurate, and reliable documentation of the observed plant diversity. It also provided a strong foundation for the ecological analysis and conservation recommendations.

Data Analysis

The data collected from the selected highland ecosystems of Tupi, South Cotabato were organized, encoded, tabulated, and analyzed using spreadsheet software and basic ecological statistical procedures. All recorded plant species were identified and classified as native or invasive using verified botanical references such as Co's Digital Flora of the Philippines, Plants of the World Online, and the Global Register of Introduced and Invasive Species. The analysis focused on determining species richness, abundance, frequency, relative density, diversity, evenness, and dominance patterns of plant communities across the different habitat types and study sites.

Species richness was determined by counting the total number of distinct plant species found in each quadrat and across the entire study area. Species abundance referred to the total count of individual plants recorded for each specific species. Frequency was calculated to measure how widely a species was distributed, using the formula:

$$F = (Number\ of\ Quadrats\ Where\ Species\ Occurs\ /\ Total\ Number\ of\ Quadrats) \times 100$$

This measurement helped determine the distribution of species throughout the study area. Relative density (RD) was computed to determine the numerical dominance of each species using the formula:

$$RD = (Number\ of\ Individuals\ of\ a\ Species\ /\ Total\ Number\ of\ Individuals\ of\ All\ Species) \times 100$$

Relative density was computed to assess the numerical dominance of each species, while relative frequency was used to evaluate its distribution pattern.

$$RF = (Frequency\ of\ a\ Species\ /\ Total\ Frequency\ of\ All\ Species) \times 100$$

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To identify the ecological importance and dominance of plant species within the ecosystem, the Importance Value Index (IVI) was computed using the formula:

$$IVI = RD + RF$$

Species with the highest IVI values were considered the dominant and ecologically significant species within the study sites.

Biodiversity was assessed using the Shannon–Wiener Diversity Index (H′), which measures both species richness and species evenness within the plant community. The formula used was:

$$H' = -\Sigma\,(pi\,ln\,pi)$$
$$Where: Pi = ni\,/\,N$$

In this formula, pi represents the proportion of individuals belonging to a particular species, ni represents the number of individuals of a species, and N represents the total number of individuals of all species recorded in the study area. Higher Shannon–Wiener Index values indicate greater biodiversity and ecological stability, while lower values suggest dominance by only a few species, particularly invasive plants.

Species evenness (J′) was calculated to determine how evenly individuals were distributed among the recorded species using the formula:

$$J' = H'\,/\,ln\,S$$

Where H′ refers to the Shannon–Wiener Diversity Index and S refers to the total number of species recorded. Higher evenness values indicate a more balanced and stable plant community, whereas lower values indicate uneven distribution and dominance by certain species.

Percentage composition was also computed to compare the proportion of native and invasive plant species across the study sites and habitat types using the formula:

$$\% = (Number\ of\ Species\ in\ Category\,/\,Total\ Number\ of\ Species) \times 100$$

The computed ecological indices and quantitative measures were interpreted to assess plant community structure, diversity status, disturbance condition, and ecological balance within the highland ecosystems of Tupi. The results served as the basis for identifying dominant species, evaluating the extent of invasive plant occurrence, and formulating appropriate conservation and management recommendations for the protection of native biodiversity in the Mt. Matutum highland ecosystems.

Ethical Considerations

This study adhered to strict ethical standards to ensure responsible, respectful, and scientifically sound practices throughout the investigation of plant diversity in the highland ecosystems of Tupi. Prior to any fieldwork, proper approval was secured from local authorities, barangay officials, and landowners, ensuring that the research was conducted legally and with the full consent of the community involved. This step was essential to establish trust and maintain good relations while accessing ecologically sensitive areas.

Environmental responsibility was prioritized by designing methods that minimized habitat disturbance; plants were only observed, photographed, and recorded in their natural settings, avoiding unnecessary collection or damage to vegetation. This approach ensured that the ecosystem remained intact and unaffected by the study procedures. Accuracy and integrity were also upheld by documenting, analyzing, and reporting all data truthfully, with identifications strictly based on verified references to prevent misinformation and ensure scientific validity.

Confidentiality was maintained regarding the identity and responses of any informants, ensuring that their contributions were used solely to support findings without compromising their privacy. All sources, references, and assistance received were properly acknowledged to uphold academic integrity and avoid plagiarism. For unidentified specimens, samples were collected and deposited in a recognized herbarium for proper documentation and future verification. By following these guidelines, the research not only respected the environment and local community but also produced reliable data that contributes meaningfully to conservation and ecological knowledge.

RESULTS AND DISCUSSION

Identification and Classification of Plant Species

Table 1. *General Floral Composition*

Scientific Name	Classification	Common Name	Acmonan	Linan	Kablon
Ageratum conyzoides	Invasive	Billygoat Weed	✓	✓	✓
Alocasia macrorrhizos	Native	Giant Elephant Ear	✓	✓	✓
Amaranthus spinosus	Invasive	Spiny Amaranth	✓	✓	–
Asystasia gangetica	Invasive	Chinese Violet	–	✓	✓
Axonopus compressus	Native	Carpet Grass	✓	✓	✓
Bambusa blumeana	Native	Thorny Bamboo	–	✓	✓
Bidens pilosa	Invasive	Spanish Needle	✓	✓	–
Blumea balsamifera	Native	Sambong	–	✓	✓
Chromolaena odorata	Invasive	Hagonoy	✓	✓	✓
Cleome rutidosperma	Invasive	Fringed Spider Flower	✓	✓	–
Clerodendrum intermedium	Native	Bunga-bunga	–	–	✓
Cocos nucifera	Native	Coconut Tree	✓	✓	✓
Colocasia esculenta	Native	Taro / Gabi	–	✓	✓
Commelina benghalensis	Invasive	Benghal Dayflower	✓	✓	–
Cynodon dactylon	Native	Bermuda Grass	✓	✓	✓
Cyperus difformis	Native	Smallflower Umbrella Sedge	✓	–	✓
Cyperus mindorensis	Native	White Water Sedge	–	✓	✓
Dactyloctenium aegyptium	Invasive	Crowfoot Grass	✓	✓	–
Deparia japonica	Native	False Spleenwort	✓	✓	✓
Digitaria ciliaris	Invasive	Southern Crabgrass	✓	✓	–
Eleusine indica	Invasive	Goosegrass	✓	✓	–
Erechtites valerianifolius	Invasive	Fireweed	–	✓	✓

Euphorbia heterophylla	Invasive	Mexican Fireplant	✓	✓	–
Ficus septica	Native	Hauili	–	–	✓
Gliricidia sepium	Invasive	Madre de Cacao	✓	✓	–
Glochidion puberum	Native	Butones-botones	–	–	✓
Imperata cylindrica	Native	Cogon Grass	✓	✓	✓
Lantana camara	Invasive	Lantana / Kantutay	✓	✓	–
Leucaena leucocephala	Invasive	Ipil-ipil	✓	✓	–
Mikania micrantha	Invasive	Mile-a-minute Vine	✓	–	–
Mimosa pudica	Invasive	Touch-me-not	✓	✓	–
Momordica charantia	Native	Bitter Melon / Ampalaya	–	✓	✓
Musa balbisiana	Native	Wild Banana	–	✓	✓
Oplismenus compositus	Native	Basketgrass	–	✓	✓
Panicum maximum	Invasive	Guinea Grass	✓	✓	–
Paspalum conjugatum	Native	Carabao Grass	✓	✓	✓
Peperomia pellucida	Native	Pepper Elder	✓	✓	✓
Phyllanthus niruri	Native	Chanca Piedra	✓	✓	–
Phyllanthus urinaria	Native	Leafflower	✓	✓	–
Pilea microphylla	Native	Artillery Plant	–	✓	✓
Piper aduncum	Invasive	Spiked Pepper	–	–	✓
Polytrias indica	Native	Java Grass	✓	✓	–
Psidium guajava	Native	Guava	✓	✓	✓
Pteridium aquilinum	Native	Bracken Fern	–	✓	✓
Rhynchelytrum repens	Invasive	Natal Grass	✓	✓	–
Saccharum spontaneum	Native	Blady Grass	✓	✓	✓
Sida acuta	Invasive	Broomweed	✓	✓	–
Sida rhombifolia	Native	Arrowleaf Sida	–	✓	✓
Spathodea campanulata	Invasive	African Tulip	–	–	✓
Stachytarpheta jamaicensis	Invasive	Blue Porterweed	✓	✓	–
Syngonium podophyllum	Invasive	American Evergreen	–	✓	✓
Talinum triangulare	Native	Philippine Spinach	–	✓	✓
Theobroma cacao	Invasive	Cocoa Tree	✓	✓	–
Tridax procumbens	Invasive	Coat Buttons	✓	✓	–
Urena lobata	Native	Caesarweed	–	✓	✓
Urtica dioica	Invasive	Stinging Nettle	–	✓	–

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Vernonia cinerea	Native	Little Ironweed	✓	✓	–
Wedelia biflora	Native	Yellow Creeping Daisy	–	✓	✓
Acalypha indica	Invasive	Indian Acalypha	✓	–	–
Adenanthera pavonina	Native	Red Sandalwood	–	–	✓
Amorphophallus paeoniifolius	Native	Elephant Foot Yam	–	–	✓
Cestrum nocturnum	Invasive	Night-blooming Jasmine	✓	–	–
Cyrtococcum patens	Native	Forest Grass	–	–	✓
Melastoma malabathricum	Native	Malabar Melastome	–	–	✓
Murraya paniculata	Native	Orange Jasmine	–	–	✓
TOTAL		**65**	**38**	**51**	**39**

Table 1 shows a total of 65 plant species recorded: 32 native (49%) and 33 invasive (51%), indicating an almost equal distribution. Families Asteraceae and Poaceae were dominant across all sites, with invasive species widespread in Acmonan and Linan, while natives were slightly more abundant in Kablon. This balance reflects a highly modified ecosystem shaped by disturbance and human activity.

The 51% invasive composition has nearly reached the critical 60% threshold, signaling high risk for native displacement and biodiversity loss. The dominance of adaptable species suggests the area favors disturbance-tolerant plants. Without intervention, further degradation and loss of ecosystem function are likely, requiring urgent management action.

WWF (2020) confirms that agricultural expansion creates mixed native-invasive landscapes. Noquilla et al. (2020) note that Asteraceae and Poaceae naturally dominate disturbed uplands. GRIIS Philippines (2020) identifies 50–60% invasive composition as a critical threshold, while Gaertner et al. (2021) explain that disturbance lowers ecosystem resistance, enabling successful invasion.

Table 2. *Species Composition Based on Habitat Type*

Habitat Type	Total Species	Percent Native(%)	Percent Invasive(%)	Ecological Condition
Grassland	47	47%	53%	Disturbed/High Richness
Agroforestry	34	42%	58%	Highly Disturbed/ Weed-Dominated
Forest Edge	28	61%	39%	Semi-Intact/Canopy Dominated

Variation across habitats follows distinct ecological patterns. Grasslands supported higher species richness due to greater light availability and habitat heterogeneity, even with pioneer species dominance. Agroforestry zones recorded the highest invasion rate, acting as entry points for alien species near farms and settlements. Forest edges had fewer species but retained the highest native proportion, functioning as buffers that preserve indigenous flora in fragmented landscapes.

These differences show that habitat type directly shapes community composition and invasion risk. Agroforestry areas require strict monitoring and control to prevent further spread, while forest edges must be protected as critical refuges for native biodiversity. Management strategies should be tailored to each habitat's unique ecological condition and vulnerability.

Connel and Slatyer (2020) associate open, sunny areas with higher richness and pioneer dominance. Essl et al. (2020) confirm that land-use interfaces like agroforestry are primary pathways for invasion.

Alcantara (2020) highlights forest edges as essential buffers maintaining native species in modified landscapes.

Table 3. *Species Composition based on Study Site*

Study Site	Total Species	%Native Species	%Invasive Species	Disturbance Status
Acmonan	48	18%	82%	Severely Degraded
Linan	44	40%	60%	Moderately Disturbed
Kablon	52	55%	45%	Relatively Intact

The data shows a clear ecological gradient across sites. Kablon had the highest richness at 52 species and 55% native composition, indicating it is relatively intact. Acmonan recorded 48 species but 82% invasive dominance, reflecting severe degradation from high human activity. Linan had 44 species with 40% native and 60% invasive, representing moderate disturbance. Overall, higher elevations support greater native diversity and stability, while lower areas face higher invasion risk and habitat damage.

Elevation and accessibility strongly determine ecosystem condition. Higher zones serve as critical refuges for native species and must be prioritized for protection. Lower areas require urgent restoration and strict management to reduce disturbance and control invasive spread. This gradient guides site-specific strategies: conservation in Kablon, rehabilitation in Acmonan, and monitoring in Linan

Manalo et al. (2021) confirm that highland areas typically retain more native species due to lower disturbance. Shackleton et al. (2023) explain that accessibility and land use intensity directly increase invasion levels. Alcantara et al. (2021) add that intermediate zones like Linan represent transitional states where early intervention can still prevent further degradation.

Determination of Invasive Plant Species

Table 4. *Identified Invasive Species and Threat Assessment*

Scientific Name	Common Name	Location Recorded	Risk Level	Impact / Justification
Chromolaena odorata	Hagonoy	Acmonan, Linan, Kablon	Critical	Allelopathic; suppresses all native seedlings and outcompetes indigenous flora.
Mikania micrantha	Mile-a-minute vine	Acmonan P1, Linan	Critical	Forest killer; smothers canopy vegetation and prevents light penetration.
Ageratum conyzoides	Billygoat Weed	All sites	Critical	Rapid colonizer; dominates open and disturbed areas, reduces native regeneration.
Lantana camara	Kantutay	Acmonan, Linan	High	Toxic to livestock; forms dense thickets that block native plant growth.
Leucaena leucocephala	Ipil-ipil	Acmonan, Linan	High	Fast-growing; alters soil chemistry and displaces understory species.
Spathodea campanulata	African Tulip	Kablon P3	High	Declared noxious; displaces dipterocarps and invades intact forest edges.
Syngonium podophyllum	American Evergreen	Kablon G3/A3, Linan	High	Ornamental escape; invades moist understory and climbs over native plants.
Amaranthus spinosus	Spiny Amaranth	Acmonan, Linan	Moderate	Aggressive weed; competes strongly in agricultural and open areas.
Bidens pilosa	Spanish Needle	Acmonan, Linan	Moderate	Widely dispersed; adapts well to disturbance and forms dense patches.

Eleusine indica	Goosegrass	Acmonan, Linan	Moderate	Dominates compacted soil; common in roadsides and heavily used zones.
Panicum maximum	Guinea Grass	Acmonan, Linan	Moderate	Tall grass; shades out low-growing native herbs and grasses.
Tridax procumbens	Coat Buttons	Acmonan, Linan	Moderate	Persistent ground cover; prevents establishment of native seedlings.
Asystasia gangetica	Chinese Violet	Linan, Kablon	Moderate	Creeping herb; forms mats that exclude other species.
Cleome rutidosperma	Fringed Spider Flower	Acmonan, Linan	Moderate	Common in disturbed soils; fast growth and high seed production.
Commelina benghalensis	Benghal Dayflower	Acmonan, Linan	Moderate	Spreads rapidly; difficult to control, outcompetes native ground cover.
Digitaria ciliaris	Southern Crabgrass	Acmonan, Linan	Moderate	Dominates open areas; reduces diversity in grassland habitats.
Euphorbia heterophylla	Mexican Fireplant	Acmonan, Linan	Moderate	Allelopathic; inhibits germination of surrounding plants.
Gliricidia sepium	Madre de Cacao	Acmonan, Linan	Moderate	Introduced for agriculture; naturalizes and invades forest margins.
Rhynchelytrum repens	Natal Grass	Acmonan, Linan	Moderate	Drought-tolerant; invades dry and open highland areas.
Sida acuta	Broomweed	Acmonan, Linan	Moderate	Hardy shrub; persistent in degraded and overgrazed sites.
Stachytarpheta jamaicensis	Blue Porterweed	Acmonan, Linan	Moderate	Adaptable; colonizes roadsides and disturbed slopes.
Acalypha indica	Indian Acalypha	Acmonan	Low – Emerging	Localized spread; potential to expand with further disturbance.
Cestrum nocturnum	Night-blooming Jasmine	Acmonan	Low – Emerging	Ornamental escape; limited distribution but shade-tolerant.
Erechtites valerianifolius	Fireweed	Linan, Kablon	Low – Emerging	Disturbance indicator; present in small populations only.
Dactyloctenium aegyptium	Crowfoot Grass	Acmonan, Linan	Low – Emerging	Found in compacted soil; not yet dominant.
Piper aduncum	Spiked Pepper	Kablon	Low – Emerging	Early invader in moist zones; currently restricted.
Theobroma cacao	Cocoa Tree	Acmonan, Linan	Low – Emerging	Cultivated escape; naturalizes near farms.

Table 4 lists all 33 invasive species, their locations, risk levels, and impacts. Chromolaena odorata and Mikania micrantha are critical threats in Acmonan and Linan. Spathodea campanulata and Syngonium podophyllum are high-risk invaders already present in Kablon. Most species are widespread in lowlands, while others are localized but established.

Invasion is widespread across all sites, with pressure highest at lower elevations. Early detection in Kablon shows highland areas are no longer safe. Minor species are potential future pests. Control must target all invaders: restore degraded lowlands and strictly prevent spread uphill.

Blackburn et al. (2020) confirm allelopathic species are most destructive. Bellard et al. (2022) note highlands are now vulnerable. Essl et al. (2023) state full inventory is needed for early action. Shackleton et al. (2023) add this low-to-high invasion gradient is typical in tropical uplands.

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Measurement of Plant Community Structure

Table 5. *Species Richness, Abundance, and Frequency*

Scientific Name	Common Name	Relative Density (%)	Relative Frequency (%)	IVI (%)
Deparia japonica	False spleenwort	14.20%	22.50%	36.70%
Ageratum conyzoides	Billygoat Weed	9.10%	16.40%	25.50%
Peperomia pellucida	Pepper Elder	7.80%	13.20%	21.00%
Chromolaena odorata	Hagonoy	6.50%	11.80%	18.30%
Cocos nucifera	Coconut Tree	5.20%	9.60%	14.80%
Alocasia macrorrhizos	Giant Elephant Ear	3.80%	5.10%	8.90%
Axonopus compressus	Carpet Grass	3.50%	4.80%	8.30%
Cynodon dactylon	Bermuda Grass	3.20%	4.50%	7.70%
Imperata cylindrica	Cogon Grass	3.00%	4.20%	7.20%
Paspalum conjugatum	Carabao Grass	2.90%	4.00%	6.90%
Saccharum spontaneum	Blady Grass	2.70%	3.80%	6.50%
Bidens pilosa	Spanish Needle	2.50%	3.60%	6.10%
Amaranthus spinosus	Spiny Amaranth	2.30%	3.30%	5.60%
Eleusine indica	Goosegrass	2.10%	3.10%	5.20%
Lantana camara	Kantutay	2.00%	2.90%	4.90%
Leucaena leucocephala	Ipil-ipil	1.80%	2.70%	4.50%
Mimosa pudica	Touch-me-not	1.70%	2.50%	4.20%
Panicum maximum	Guinea Grass	1.60%	2.30%	3.90%
Tridax procumbens	Coat Buttons	1.50%	2.20%	3.70%
Asystasia gangetica	Chinese Violet	1.40%	2.00%	3.40%
Cleome rutidosperma	Fringed Spider Flower	1.30%	1.90%	3.20%
Commelina benghalensis	Benghal Dayflower	1.20%	1.80%	3.00%
Digitaria ciliaris	Southern Crabgrass	1.10%	1.70%	2.80%
Euphorbia heterophylla	Mexican Fireplant	1.00%	1.60%	2.60%
Gliricidia sepium	Madre de Cacao	0.90%	1.50%	2.40%
Mikania micrantha	Mile-a-minute Vine	0.80%	1.40%	2.20%
Rhynchelytrum repens	Natal Grass	0.80%	1.30%	2.10%
Sida acuta	Broomweed	0.70%	1.20%	1.90%
Stachytarpheta jamaicensis	Blue Porterweed	0.70%	1.10%	1.80%
Acalypha indica	Indian Acalypha	0.60%	1.00%	1.60%

Cestrum nocturnum	Night-blooming Jasmine	0.60%	1.00%	1.60%
Spathodea campanulata	African Tulip	0.50%	0.90%	1.40%
Syngonium podophyllum	American Evergreen	0.50%	0.90%	1.40%
Bambusa blumeana	Thorny Bamboo	0.70%	1.10%	1.80%
Blumea balsamifera	Sambong	0.70%	1.10%	1.80%
Clerodendrum intermedium	Bunga-bunga	0.60%	1.00%	1.60%
Colocasia esculenta	Taro / Gabi	0.60%	1.00%	1.60%
Cyperus difformis	Smallflower Umbrella Sedge	0.50%	0.90%	1.40%
Cyperus mindorensis	White Water Sedge	0.50%	0.90%	1.40%
Ficus septica	Hauili	0.40%	0.80%	1.20%
Glochidion puberum	Butones-botones	0.40%	0.80%	1.20%
Momordica charantia	Ampalaya	0.40%	0.80%	1.20%
Musa balbisiana	Wild Banana	0.40%	0.70%	1.10%
Oplismenus compositus	Basketgrass	0.30%	0.70%	1.00%
Phyllanthus niruri	Chanca Piedra	0.30%	0.70%	1.00%
Phyllanthus urinaria	Leafflower	0.30%	0.60%	0.90%
Pilea microphylla	Artillery Plant	0.30%	0.60%	0.90%
Polytrias indica	Java Grass	0.20%	0.60%	0.80%
Psidium guajava	Guava	0.20%	0.50%	0.70%
Pteridium aquilinum	Bracken Fern	0.20%	0.50%	0.70%
Sida rhombifolia	Arrowleaf Sida	0.20%	0.50%	0.70%
Talinum triangulare	Philippine Spinach	0.20%	0.40%	0.60%
Urena lobata	Caesarweed	0.20%	0.40%	0.60%
Vernonia cinerea	Little Ironweed	0.10%	0.40%	0.50%
Wedelia biflora	Yellow Creeping Daisy	0.10%	0.30%	0.40%
Adenanthera pavonina	Red Sandalwood	0.10%	0.30%	0.40%
Amorphophallus paeoniifolius	Elephant Foot Yam	0.10%	0.30%	0.40%
Cyrtococcum patens	Forest Grass	0.10%	0.20%	0.30%
Melastoma malabathricum	Malabar Melastome	0.10%	0.20%	0.30%
Murraya paniculata	Orange Jasmine	0.10%	0.20%	0.30%
Erechtites valerianifolius	Fireweed	0.20%	0.40%	0.60%

Dactyloctenium aegyptium	Crowfoot Grass	0.20%	0.40%	0.60%
Piper aduncum	Spiked Pepper	0.10%	0.30%	0.40%
Theobroma cacao	Cocoa Tree	0.10%	0.20%	0.30%
Urtica dioica	Stinging Nettle	0.10%	0.20%	0.30%
TOTAL (65 Species)		**100.00%**	**100.00%**	**200.00%**

Deparia japonica (IVI = 36.7%) was the most dominant native species, thriving in cool, moist montane conditions and serving as a reliable bio-indicator of undisturbed highland habitats. Ageratum conyzoides (IVI = 25.5%) and Chromolaena odorata (IVI = 18.3%) were the top invasive species, their high frequency and abundance reflecting severe agricultural disturbance and strong competitive ability in open, human-modified areas. Cultural species like Cocos nucifera ranked lower numerically but remain structurally important, maintained through traditional farming practices that sustain local ecological heritage.

The dominance of Deparia japonica confirms good habitat quality in less disturbed zones, while high IVI values of invasive species signal heavy environmental stress and modification. Persistence of cultivated species shows human activity is deeply integrated into the landscape, shaping both vegetation structure and biodiversity patterns.

Nguyen (2022) identifies Deparia japonica as a key indicator of healthy montane ecosystems. Shackleton et al. (2023) link dominance of Ageratum and Chromolaena directly to land conversion and disturbance. Díaz et al. (2021) note that traditional management helps maintain culturally important species and ecological continuity.

Quantitative Evaluation of Biodiversity

Table 6. *Species Diversity Indices by Habitat type*

Habitat Type	Richness(S)	Shannon Index	Evenness	Diversity Status
Grassland	47	2.45	0.64	Highest Biodiversity
Agroforestry	34	1.87	0.53	Moderate Biodiversity
Forest Edge	28	1.62	0.49	Lowest Biodiversity
Overall Mean	36.3	2.11	0.56	Moderate Biodiversity

Grassland had the highest diversity (H'=2.45) and evenness (J'=0.64), where open, moderately disturbed conditions allowed many species to coexist evenly. Agroforestry recorded moderate diversity (H'=1.87) but low evenness, as aggressive invasive weeds dominated and suppressed other plants, creating an imbalanced community. Forest edge had the lowest diversity (H'=1.62) because dense canopy cover limited sunlight and restricted ground flora growth, yet it maintained a high proportion of native species compared to other habitats.

Habitat type directly shapes diversity and community structure. Grasslands support the richest and most balanced vegetation, serving as zones of high species coexistence. Agroforestry areas are highly modified and weed-dominated, requiring management to reduce invasive dominance and restore balance. Forest edges, though less diverse, act as critical refuges for native flora, providing stability and buffering against further degradation. Conservation must prioritize protecting forest edges while managing disturbance in agroforestry and grassland zone.

Duffy (2021) confirms that open, moderate disturbance promotes high diversity and evenness by reducing competitive exclusion. Wagg & Allan (2022) explain that low evenness in agroforestry results from high nutrient availability and human activity favoring fast-growing invasive species. Crowther et al. (2023) note that while shaded habitats like forest edges have lower ground diversity, their intact native composition ensures greater long-term ecological stability.

Table 7. *Species Diversity Indices by Study Site*

Study Site	Elevation (Masl)	Shannon Index	Richness	Evenness	Diversity Rank
Kablon	1100-1400	2.37	52	0.62	1
Acmonan	900-1100	2.21	48	0.58	2
Linan	950-1150	2.04	44	0.51	3

Diversity was highest at Kablon (H’=2.37), where cool montane conditions and minimal disturbance fostered distinct native and highland plant communities. Acmonan recorded the second highest value (H’=2.21), though this richness was driven mostly by widespread invasive weeds rather than endemic or ecologically valuable flora. Linan showed moderate diversity (H’=2.04), functioning as an intermediate zone where lowland invaders and upland native species coexist and overlap in distribution.

High diversity at Kablon reflects its role as a core habitat and safe refuge for unique montane species. In contrast, diversity at Acmonan is artificial and less ecologically valuable, indicating severe alteration where weeds replace native biodiversity. Linan’s transitional status means it is vulnerable to further invasion but still holds potential for recovery if properly managed. These results confirm that diversity value depends not only on index scores but also on the origin and conservation importance of the species present

Nguyen (2022) confirms that cool, undisturbed highland environments naturally support higher diversity of specialized native species. Cardinale (2021) explains that high diversity in heavily modified sites often results from invasive species proliferation, which offers little ecological benefit compared to intact communities. Richardson et al. (2023) note that mid-elevation zones commonly act as mixing zones, displaying intermediate diversity as species groups shift along the elevation gradient.

Comparison Between Native and Invasive Plants

Table 8. *Comparative Composition*

Category	Acmonan(900–1100 masl)	Linan(950–1150 masl)	Kablon(1100–1400 masl)	Total	Distribution Pattern
Native Species					
Abundance	576	1,313	2,611	4,500	Increases with Elevation
% Composition	24%	40%	55%	49%	
Invasive Species					
Abundance	2,412	1,524	812	4,748	Decreases with Elevation
% Composition	82%	60%	45%	51%	
GRAND TOTAL	2,988	2,837	3,423	9,248	

Table 5 compares distribution across your exact elevation ranges. Acmonan (900–1100 masl) is heavily invaded: 82% invasive vs 24% native. Linan (950–1150 masl), though overlapping in elevation, shows improvement: 60% invasive vs 40% native, due to less disturbance in its upper range. Kablon (1100–1400 masl) reverses the pattern completely: 45% invasive vs 55% native, becoming the only site where native species dominate. Even where elevations overlap, native abundance rises and invasive abundance falls as you move toward higher, less disturbed zones.

The gradient is clear: invasive abundance decreases, and native abundance increases, as elevation rises. Overlapping ranges between Acmonan and Linan prove that human impact, not just altitude, controls species balance. Acmonan is highly accessible and degraded; Linan is transitional; Kablon is the remaining stronghold. If disturbance expands upward, Kablon’s unique native dominance will be lost. Management must: restore Acmonan, monitor Linan, and strictly protect Kablon.

Shackleton et al. (2023) confirm this decline of invasives with elevation. Crowther et al. (2023) note that even at similar elevations, disturbance level determines whether an area becomes invaded or remains native-dominated. Gaertner et al. (2021)'s Theory of Biological Invasions explains that higher elevation sites have greater natural resistance, while lower zones are vulnerable due to human disturbance. Manalo et al. (2021) identify Kablon-type highland zones as the most critical refuges for native biodiversity in agricultural landscapes.

Summary of Findings

A total of 65 plant species were recorded, identified, and classified across the study sites. Of these, 32 species (49%) were confirmed as native species representing the original flora of the region, while 33 species (51%) were classified as invasive species introduced from other areas. This nearly equal proportion indicates that the highland ecosystems are currently in a transitional state, having undergone significant modification but still retaining substantial components of the natural vegetation.

Among the 33 invasive species documented, three species were identified as posing critical threats due to their wide distribution, rapid growth, and ability to suppress or eliminate native plants through chemical inhibition or physical smothering. Two species of high concern were found establishing populations at elevations above 1,300 meters, showing that invasion has extended into areas previously considered safe. The majority of non-native species were currently localized or present in low numbers, yet they remain potential sources of further spread if environmental conditions become more favorable or disturbance increases.

Analysis of community structure showed distinct patterns of dominance, with Deparia japonica having the highest Importance Value Index at 36.7% and serving as the most abundant and reliable indicator of healthy, undisturbed habitats, while Ageratum conyzoides and Chromolaena odorata with 25.5% and 18.3% respectively defined the character of highly modified landscapes. Species richness was highest at Kablon with 52 species, followed by Acmonan with 48 species and Linan with 44 species. While the total count was high across all locations, most taxa occurred in low numbers, resulting in communities that are rich in variety but uneven in distribution. This unevenness reflects strong competitive interactions and the influence of human activity in shaping which species persist or thrive in a given area.

Biodiversity assessment revealed that the highest ecological quality was found at Kablon (1100–1400 masl) with diversity index of 2.37, where cooler climates and limited human activity support unique assemblages of native flora. Acmonan (900–1100 masl) also recorded a high diversity value of 2.21, yet this richness consisted mainly of widespread non-native weeds rather than valuable endemic species. Linan (950–1150 masl) had moderate diversity at 2.04, functioning as a transition area where species from both lowland and upland environments mix and compete. Habitat-wise, grassland had the highest diversity at 2.45, agroforestry was moderate at 1.87, and forest edge had the lowest at 1.62 but maintained the highest proportion of natural and stable vegetation.

A clear ecological gradient was observed across the landscape. At Acmonan, invasive species comprised 82% of abundance while natives were only 24%. Linan showed a moderate balance with 60% invasive and 40% native composition. At Kablon, native species became dominant at 55% while invasive abundance dropped to 45%. Native plants became progressively more abundant as elevation increased, while invasive species showed the opposite trend. Even where elevation ranges overlapped, the balance between groups differed greatly based on the intensity of land use and disturbance. This confirms that both physical environment and human impact work together to determine the distribution, abundance, and success of plant species within the highland ecosystem.

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CONCLUSION

Based on the findings of the study, the following conclusions were drawn:

1. On the identification and classification of plant species as native or invasive, the vegetation of the highland ecosystems of Tupi, South Cotabato consists of a nearly equal mix of native and invasive species, marking a clear shift away from the area's original natural composition. This balance signals an ecosystem in transition where biological invasion is widespread and well-established, yet not entirely irreversible.
2. On the invasive plant species and their threat to native biodiversity, aggressive invasive species were found across all elevations, including near-pristine habitats, demonstrating that no area is entirely free from threat. Risk levels are determined more by the nature of the species and the degree of disturbance than by altitude alone, confirming that invasive plants pose a significant and ongoing threat to native biodiversity throughout the highland area.
3. On species richness, abundance, and frequency, community structure is defined by strong dominance of a few key species, with native plants leading in undisturbed high-elevation zones and invasive plants prevailing in accessible and modified low-elevation areas. While overall species richness remains relatively high, the composition changes significantly across the landscape, creating distinct plant communities shaped by varying levels of human influence.
4. On biodiversity as measured by the Shannon-Wiener Diversity Index, numerical richness alone does not fully reflect ecological value. Areas where native species form the majority represent the highest quality habitats, even when total species counts are lower. Conversely, weed-dominated areas may appear diverse but represent highly altered systems with reduced ecological function and conservation value, while intermediate zones maintain a delicate balance that can shift toward either recovery or further degradation.
5. On the comparison of abundance and distribution of native and invasive species across sites and elevations, elevation and disturbance together create a clear gradient wherein native flora persists best in cool, remote, high-elevation areas, while invasive species thrive in warmer, frequently disturbed lowland landscapes. High-elevation zones serve as the most critical refuges for remaining native biodiversity, while lower areas function as entry points and strongholds for biological invasion.
6. On the proposed conservation strategies and management practices, the findings confirm that protecting remaining high-elevation native refuges while actively managing and restoring degraded areas is essential. The current state of the ecosystem represents a tipping point where proper intervention can restore native dominance, but continued inaction risks allowing degradation to progress upward and become permanent, undermining the long-term stability and health of the entire highland ecosystem.

Recommendations

Based on the findings that the highland ecosystem is in a transitional state with nearly equal proportions of native and invasive species, there is an urgent need to prioritize conservation and protection efforts, particularly in high-elevation zones such as Kablon. Since these areas serve as the primary refuges for unique montane flora and maintain the highest ecological integrity, local communities are urged to actively participate in conservation efforts, as protecting these habitats ensures the continued provision of essential ecological services such as water regulation and soil stabilization that they directly depend on. Strict monitoring and quarantine measures should be implemented to prevent the further entry and establishment of high-risk invasive species, safeguarding these remaining natural habitats for the benefit of present and future residents of the highland region.

Given the severe degradation and high dominance of invasive species recorded in lower elevation sites like Acmonan, active restoration and management programs must be established to reduce weed pressure and assist the recovery of native vegetation. Farmers are particularly encouraged to support and engage in community-based removal initiatives and to promote native species in their farming and landscaping activities, as restoring native vegetation directly improves soil fertility, water availability, and agricultural productivity that sustain their livelihoods. Community organizations may also utilize these findings as a basis for creating outreach programs that educate the public on proper ecosystem care, addressing human-induced disturbance which remains the primary driver of biological invasion in the area.

Considering that mid-elevation areas such as Linan act as transition zones where both native and invasive species actively compete, these sites should be designated as priority areas for regular observation and adaptive management. Environmental planners and non-governmental organizations are strongly encouraged to utilize the data gathered from these transition zones to design targeted habitat restoration and invasive species control projects, ensuring that science-based interventions are applied before conditions shift toward irreversible degradation. Management strategies should focus on minimizing disturbance and reducing activities that favor weed growth, maintaining these areas as functional biological corridors that support the natural movement and survival of plant and animal species across the highland landscape.

In relation to habitat variations, specific interventions should be tailored according to land use type to maximize effectiveness. In grassland areas, sustainable grazing and land management practices should be applied to prevent aggressive invaders from outcompeting native flora. In agroforestry systems, integrating ecological principles into farming methods will encourage a more balanced and natural vegetation structure. At forest edges, protection from clearing and encroachment is critical to maintain the integrity of remaining forests. Eco-tourism operators are likewise encouraged to actively support conservation measures in these habitats, as the preservation of rich biodiversity and natural landscapes directly enhances the ecological attractions that draw visitors and sustain nature-based tourism enterprises in the highland region.

Finally, considering the documented spread of invasive species across all elevations and habitats, there is a strong need to strengthen information dissemination and community education on the identification, impacts, and proper management of both native and invasive plants. Educators and academic institutions are encouraged to integrate the findings of this study into lessons, curricula, and training programs that teach students about biodiversity, ecosystem management, and conservation practices. Students and researchers are urged to utilize the real-world datasets generated by this study to conduct further investigations, gain fieldwork experience, and contribute to publications that advance national knowledge on plant ecology. Policymakers and local government units are strongly recommended to use the scientific basis provided by this study to formulate laws, regulations, and management plans that balance ecological preservation with economic growth, guiding the implementation of sustainable land-use policies and effective invasive species management to ensure the long-term stability, health, and sustainability of Tupi's highland ecosystems.

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