ANT-ICS AND APPETITES: MAPPING ANT (FORMICIDAE) DIVERSITY AND RESOURCE SELECTION IN AGUMBE

by

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Under the supervision of

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July 2026

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I hereby declare that the work conducted under the thesis entitled **"ANT-ICS AND APPETITES: MAPPING ANT (FORMICIDAE) DIVERSITY AND RESOURCE SELECTION IN AGUMBE"**, is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science** at the **Academy of Scientific and Innovative Research**. This research work has been carried out under the guidance and supervision of **Mr. Ritesh Kumar Gautam, Scientist-C**, and co-supervision of **Dr. Vishnupriya Kolipakam, Scientist-E** of Wildlife Institute of India, Dehradun. The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my own work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.

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Ashwati Biju has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

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DECLARATION

I, **Ashwati Biju**, a student of the **20th MSc Wildlife Science**, hereby declare that the work conducted under the thesis entitled **"Ant-ics and Appetites: Mapping Ant Diversity and Resource Selection"** is a record of original and independent research work carried out by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science at the Academy of Scientific and Innovative Research**.

I further declare that no generative artificial intelligence (AI) tools were used in the development, drafting, or formatting of this thesis. I affirm that the thesis is the result of my own academic and research work.

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4 Abstract

Ants are important components of terrestrial ecosystems, yet information on their diversity, behaviour, and resource use in non-protected landscapes of the Western Ghats remains limited. This study investigated ant diversity, community composition, behaviour, morphometrics, and resource selection across forest patches, grasslands, and areca plantations in the Agumbe landscape of the central Western Ghats.

Field surveys were conducted between December 2025 and March 2026 using visual encounter surveys and active hand collection. Ant diversity, abundance, community composition, behaviour, and morphometric traits were documented. Resource selection experiments were conducted on *Trichomyrmex* colonies using sugar, rice, and seeds that differed in physical texture.

A total of 75 ant species, 423 occurrence records, and 10,284 individuals were recorded. Forest patches supported the highest species richness, abundance, and diversity, while plantations and grasslands supported fewer species. Community composition differed significantly among habitat types, with habitat characteristics influencing ant assemblages more strongly than stream position. Behavioural observations documented a range of ecological roles, including predation, scavenging, honeydew collection, seed collection, brood transport, recruitment, and nest maintenance. **The study also recorded ten putatively undescribed species, new state records, and worker polymorphism in *Lepisiota wroughtonii*.** Resource selection experiments showed a clear preference hierarchy of Sugar > Rice > Seeds, indicating that resource characteristics might influence foraging decisions.

The findings highlight the ecological and taxonomic importance of the Agumbe landscape and provide baseline information on ant diversity, behaviour, and resource use in the central

Western Ghats. The study also emphasizes the importance of forest patches for conserving ant biodiversity in human-modified landscapes.

5 Introduction and Literature Review

5.1 Ecological Importance of Ants

“Ants are everywhere, yet they often go unnoticed”(Wilson,1971). Beneath our feet and across almost every terrestrial habitat, they perform essential ecological functions, influencing soil processes, nutrient cycling, seed dispersal, predation, scavenging, and the dynamics of many other organisms. Their complex social organisation and remarkable communication systems have contributed to their success as one of the most dominant insect groups on Earth. Despite this, ants are often underrepresented in ecological research. Studying ants not only reveals the ecology of a highly successful group of organisms but also provides valuable insights into the functioning of terrestrial ecosystems as a whole (AntWiki).

Ants are among the most diverse and ecologically important groups of insects globally. According to AntCat, the family Formicidae currently comprises 16 extant subfamilies, 38 tribes, 350 genera, and 14,451 valid extant species, along with several fossil taxa. Their success is linked to their social organisation, flexible foraging behaviour, ability to exploit diverse food resources, and capacity to occupy a wide range of habitats.

5.2 Social Organisation and Ecological Success of Ants

Ants are highly social insects that live in colonies ranging from a few individuals to thousands. A typical colony consists of a reproductive queen, numerous sterile female workers, and developing brood, including eggs, larvae, and pupae. Workers perform most colony tasks, including nest construction, foraging, brood care, defence, and maintenance of the colony. Winged queens and males are usually produced seasonally and leave the nest to

mate and establish new colonies. In some species, winged queens are absent, and reproduction may be carried out by specialized worker-like females known as ergatoid queens (Wilson, 1971).

The ecological success of ants is closely linked to their highly organized social structure. In most species, the worker caste is responsible for the daily functioning of the colony. Worker ants may be similar in size, known as monomorphic, or may show variation in size, known as polymorphic or dimorphic. In polymorphic and dimorphic species, larger workers often have disproportionately larger heads and mandibles, which may be associated with specialized tasks such as defence, food processing, or nest protection.

A remarkable feature of ant societies is their division of labour. Different workers perform different roles within the colony, and these roles may change with age. Young workers often remain inside the nest and care for eggs, larvae, and pupae. As they mature, they may take part in nest construction and maintenance, and later become foragers that leave the nest to search for food. In some species, worker size also influences task allocation, with larger workers performing defensive roles and smaller workers being more active in foraging. This division of labour, together with sophisticated chemical communication, allows ant colonies to function as highly coordinated units and exploit resources efficiently (Wilson, 1971).

5.3 Ecological Niches and Habitat Use

Ants occupy a remarkable diversity of ecological niches and are among the most successful organisms in terrestrial ecosystems. They occur in nearly all terrestrial habitats and function as predators, scavengers, herbivores, granivores, omnivores, and mutualists. Through these roles, ants influence nutrient cycling, energy flow, soil processes, and the population dynamics of many other organisms (Wilson, 1971; Hölldobler & Wilson, 1990; Wilson & Hölldobler, 2005).

This ecological success is closely linked to their ability to exploit a wide range of habitats and nesting sites. Ants inhabit arboreal, epigeic, leaf-litter, and subterranean environments, using available resources in different ways to build and maintain their nests (Hölldobler & Wilson, 1990; Steiner et al., 2010). Nests may be established in soil, leaf litter, rotting wood, hollow twigs, rock crevices, abandoned insect galleries, snail shells, and living vegetation. While some species occupy small and specialized nesting sites, others construct extensive underground colonies with complex tunnel systems and multiple chambers.

Many arboreal ants nest in tree cavities, dead wood, or epiphytic plants, sometimes forming mutualistic associations with plants. In contrast, several subterranean species spend most of their lives within the soil, where they forage, reproduce, and interact with other soil organisms. Ant colonies also show diverse nesting strategies, ranging from permanent occupation of a single nest to the use of multiple interconnected nests. Some species relocate their nests in response to disturbance, environmental conditions, competition, or resource availability, while army ants and some other groups show nomadic nesting behaviour. The ability of ants to exploit diverse habitats, resources, and nesting strategies has enabled them to occupy ecological roles ranging from top invertebrate predators to important ecosystem engineers (AntWiki).

5.4 Ant Diversity and Research Status in India

India is recognized as one of the world's 17 megadiverse countries and supports an exceptional variety of ecosystems, ranging from the Himalayas and tropical rainforests to deserts, grasslands, wetlands, and coastal habitats. The country includes four global biodiversity hotspots: the Himalaya, Indo-Burma, Western Ghats–Sri Lanka, and Sundaland, represented by the Nicobar Islands. This environmental diversity has contributed to high species richness and endemism across many plant and animal groups.

Among terrestrial invertebrates, ants form one of the most diverse and ecologically significant groups. The first comprehensive checklist of Indian ants documented 828 valid species and subspecies belonging to 100 genera (Bharti et al., 2016). Continued taxonomic revisions, faunal surveys, and new species descriptions have increased this number, with recent estimates suggesting approximately 887 species distributed across more than 100 genera in India.

Research on Indian ants has historically been dominated by taxonomy, systematics, and faunal inventories, beginning with the pioneering work of Bingham (1903) and later expanded by several Indian myrmecologists. Over the past two decades, major efforts have focused on documenting species diversity, updating regional checklists, describing new species, and revising taxonomic groups. These studies have greatly improved our understanding of Indian ant diversity and distribution.

However, ecological studies on Indian ants remain comparatively limited. Existing research has mostly focused on community composition, diversity patterns across habitats, bioindicator potential, invasive species, and ant–plant interactions. Although studies from the Western Ghats, northeastern India, and selected protected areas have improved our understanding of ant assemblages, information on ant behaviour, resource utilization, food preference, and habitat-level variation remains fragmented. Non-protected landscapes such as plantations, agroforestry systems, forest edges, and human-modified habitats remain especially underexplored, despite their potential to support diverse ant communities.

5.5 Background

Ant ecology has received considerable attention globally because ants are abundant, diverse, and strongly involved in ecosystem processes. Studies on ant communities have shown that ant diversity and composition vary with habitat type, vegetation structure, disturbance,

microclimate, soil conditions, and resource availability (Andersen, 1997; Parr et al., 2022). In tropical ecosystems, ants often occupy multiple trophic roles and respond sensitively to environmental change, making them useful organisms for studying community structure and ecosystem functioning (Hölldobler & Wilson, 1990; Parr et al., 2022).

Foraging ecology is a central theme in ant research because foraging links colony needs with resource availability in the environment. Ants collect a wide variety of food resources, including sugars, seeds, dead insects, live prey, plant exudates, nectar, honeydew, and other organic material. Their foraging decisions are influenced by colony requirements, resource quality, distance from the nest, competition, predation risk, and the physical characteristics of the resource (Traniello, 1989; Gordon, 2010).

Resource selection in ants is often shaped by food type and nutritional requirement. Carbohydrate-rich resources such as nectar, honeydew, and sugars provide rapid energy for worker activity, while protein-rich resources support larval growth and colony development. Granivorous ants collect seeds as food resources, while omnivorous ants may shift between seeds, sugars, prey, and scavenged material depending on availability (Blüthgen & Fiedler, 2004; Kay, 2004).

The physical properties of resources can also influence ant foraging behaviour. Resource size, weight, shape, surface texture, and ease of handling may affect whether ants select, recruit to, or transport a particular item. Smooth, hard, or rounded resources may be more difficult to grip or carry, while rougher or irregular resources may be easier for workers to handle. Similarly, very large or heavy food items may require cooperative transport or recruitment of additional workers (Traniello, 1989; Vieira et al., 2024). Similar effects of resource structure have been reported across animal taxa, with food hardness influencing selection in rodents, seed structure and handling efficiency shaping preferences in granivorous birds, and

mechanical properties affecting food selection and processing in primates (Coiner-Collier et al., 2016; DePasquale et al., 2025; Hrabar & Perrin, 2002; Jiang & Yi, 2025; Sako et al., 2002).

Behavioural plasticity is another important feature of ant foraging ecology. Ants can adjust their foraging behaviour according to resource availability, competition, disturbance, weather, and habitat structure. Some species forage individually, while others recruit nestmates and form trails. Some ants specialize on particular resources, whereas others are generalists capable of exploiting a wide range of food types (Hölldobler & Wilson, 1990; Gordon, 2010).

Habitat structure also affects ant foraging and resource use. Leaf litter, soil texture, vegetation cover, fallen branches, coarse woody debris, and canopy conditions can influence ant movement, nesting, and resource discovery. In forests, leaf litter and dead wood provide important nesting and foraging spaces, while in plantations and open habitats, changes in vegetation complexity and microclimate may influence which species are able to persist (Andersen, 1997; Parr et al., 2022).

In India, ant research has provided strong taxonomic and distributional foundations, but behavioural and resource-use studies remain relatively fewer. In the Western Ghats, several studies have documented ant diversity and community composition across forests, plantations, and disturbed habitats (Bharti et al., 2016). However, fewer studies have examined how ants use different food resources or how resource characteristics such as surface texture and morphology influence foraging choices. This gap is important because resource use directly links ant behaviour with ecological function and may help explain how species coexist and contribute to ecosystem processes in both natural and modified landscapes.

5.6 Research Gap and Rationale

Despite considerable advances in ant ecology globally, studies in India remain largely focused on taxonomy and species inventories. Information on how ant diversity, behaviour, and resource use vary across habitats remains limited, particularly in non-protected landscapes of the Western Ghats. Furthermore, the influence of resource characteristics such as morphology and surface texture on foraging preferences has received little attention.

Many landscapes outside protected areas, including agroforestry systems, plantations, grasslands, and forest fragments, remain underexplored despite their potential to support diverse ant communities. These habitats are important because they form part of the larger landscape matrix and may influence biodiversity beyond protected areas. Understanding ant communities in such landscapes is therefore important for both ecological research and conservation planning.

This study originates from the need to bridge the gap between species inventories and ecological understanding. Instead of focusing only on species lists, it integrates ant diversity surveys with behavioural observations and resource selection experiments. The morphometric component is included as a baseline effort to document selected body measurements of ant species recorded in the study area. This helps build a preliminary morphological database that can support future ecological and taxonomic studies, without overstating its role as a direct test of functional performance.

5.7 Present Study

This study combines ant diversity surveys, behavioural observations, resource selection experiments, and selected morphometric measurements to understand the ecology of ants in the Agumbe landscape of the central Western Ghats. Field surveys were conducted across

forest patches, grasslands, and areca plantations to document ant diversity, abundance, and community composition.

Behavioural observations were used to record the activities of selected ant taxa, including foraging, scavenging, seed collection, honeydew collection, nest maintenance, brood transport, and other visible behaviours. Resource selection experiments were conducted to examine how ants utilize available food resources and whether characteristics such as resource morphology and surface texture influence foraging choices. In particular, the experiment compared the use of sugar, rice, and seeds, which differed in texture and structure.

The main aim of this study is to understand how ant diversity, behaviour, and resource use vary across different habitats. By examining species occurrence, community composition, behavioural patterns, and resource preferences, this research seeks to identify the factors that shape ant communities in the region. The study provides baseline information on ant communities in the central Western Ghats and contributes to a better understanding of how ants interact with and utilize resources in both natural and human-modified habitats.

6 Aim

To assess ant community diversity, document baseline behavioural patterns, and evaluate how resource characteristics influence resource selection in the Agumbe landscape of the Central Western Ghats, India.

7 Research Questions

1. How do different habitat types influence ant species diversity and community composition in the Agumbe landscape?

2. How do morphometric traits of food resources, particularly surface texture, influence resource selection by Trichomyrmex ants?

8 Objectives and Activities

Objective 1: Assess ant diversity, functional traits, and behaviour across habitat types in the Agumbe landscape.

Sub-objective 1: Quantify and compare ant species diversity and community composition across forest, grassland, and areca plantation habitats.

Sub-objective 2: Develop a morphometric database for selected ant species.

Sub-objective 3: Document ant behavioural ecology, including foraging strategies, resource use, recruitment, nesting activities, and species interactions.

Objective 2: Evaluate resource selection and food preference in *Trichomyrmex* colonies.

Assess the influence of resource characteristics, particularly physical texture, on foraging decisions and food preference patterns in *Trichomyrmex* ants.

9 Study Area

The selected area for fieldwork is the tropical lowland evergreen forest landscape of Agumbe (13.5087° N, 75.0959° E) in Karnataka's Shivamogga district, within the Shivamogga Forest Division (Fig. 1). The study was conducted in non-protected habitats in and around Agumbe, including forest patches, grasslands, and areca-based agroecosystems located outside the boundaries and buffer zones of protected areas.

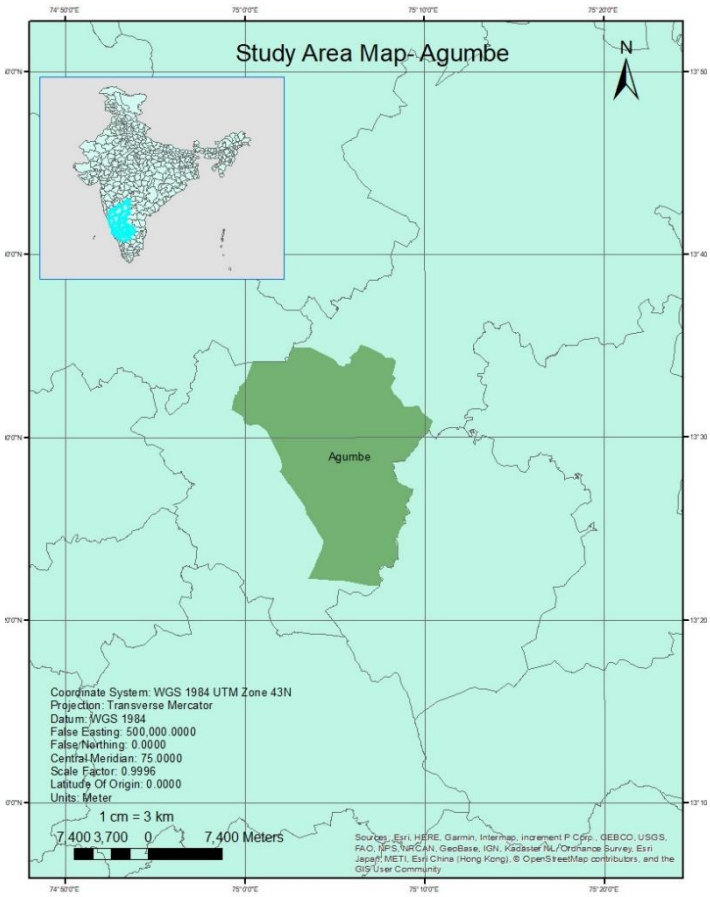


Figure 1. Study Area Overview

Situated in the central Western Ghats, Agumbe is widely recognized for its extensive rainforest cover, high rainfall, and exceptional biological diversity. As part of the Western Ghats biodiversity hotspot and UNESCO World Heritage landscape, the region supports a rich assemblage of endemic and threatened flora and fauna, making it an important area for ecological research and conservation.

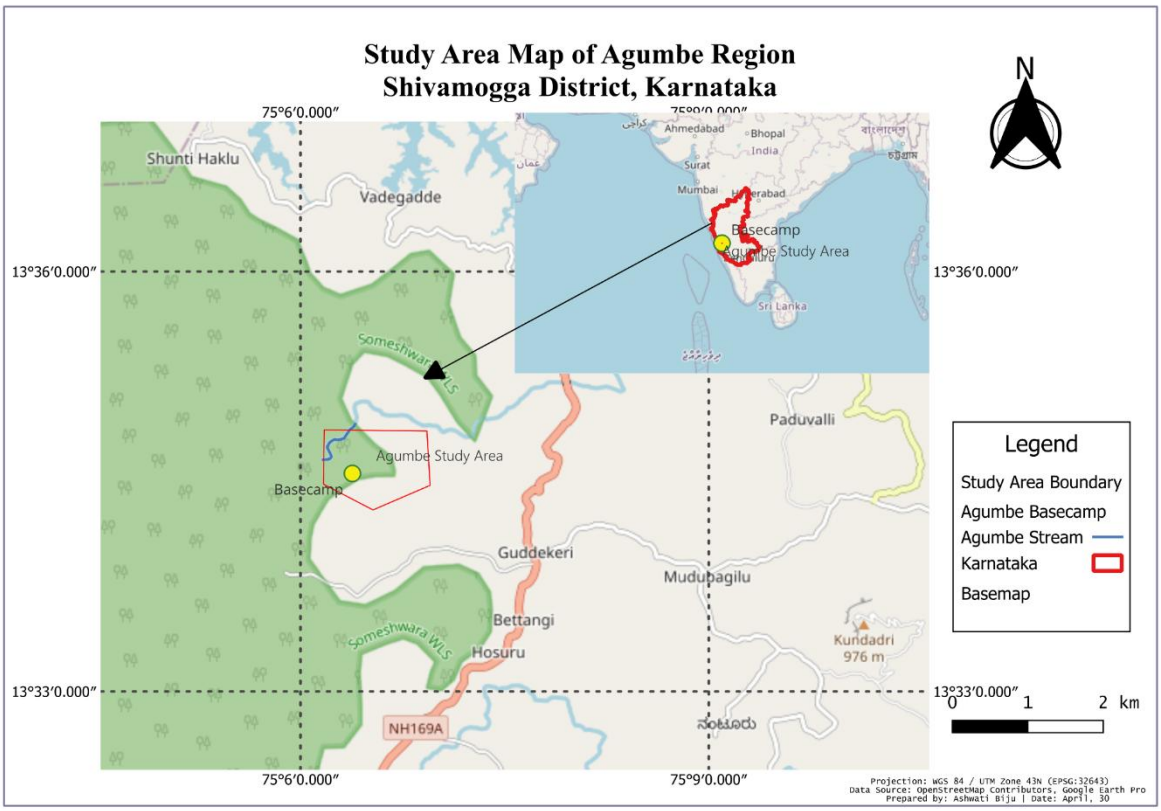


Figure 2. Study Area Map of Agumbe Region

The vegetation of Agumbe belongs to the *Dipterocarpus indicus–Humboldtia brunonis–Poeciloneuron indicum* type of tropical wet evergreen forest described by Pascal (1988). The forests are characterized by a multi-layered canopy, dense understory vegetation, abundant lianas, climbers, epiphytes, canes, palms, and a rich diversity of pteridophytes. Dominant tree species include *Dipterocarpus indicus*, *Poeciloneuron indicum*, *Mesua ferrea*, *Vateria indica*, *Humboldtia brunonis*, and several species of *Garcinia*. Large emergent and old-growth trees form a closed canopy, creating humid and shaded conditions that support a diverse assemblage of plants, fungi, and invertebrates. The region is particularly notable for its rich fern flora, including numerous terrestrial, lithophytic, and epiphytic species that thrive under the constantly moist rainforest conditions.

Agumbe experiences a perhumid tropical climate and receives some of the highest annual rainfall recorded in India, averaging approximately 7,620 mm per year. Its exceptionally high rainfall has earned it the popular title of the **"Cherrapunji of South India."** Temperatures remain relatively stable throughout the year, ranging between 22.2°C and 23.6°C, with a mean annual temperature of approximately 23.5°C. Situated at an elevation of about 643 m above sea level, the forests maintain dense canopy cover of approximately 80–85%, creating cool and humid microclimatic conditions favourable for rainforest-dependent flora and fauna. According to Champion and Seth's (1968) forest classification, the area falls under the category of Southern Tropical Wet Evergreen Forests.

The region supports an exceptional diversity of vertebrate fauna characteristic of the central Western Ghats. Mammals recorded from the landscape include the leopard (*Panthera pardus*), lion-tailed macaque (*Macaca silenus*), bonnet macaque (*Macaca radiata*), Hanuman langur (*Semnopithecus* spp.), Indian giant squirrel (*Ratufa indica*), flying squirrels, Indian flying fox (*Pteropus giganteus*), barking deer (*Muntiacus muntjak*), Indian mouse deer (*Moschiola indica*), slender loris (*Loris lydekkerianus*), tree shrews, civets, and several other species of bats. Agumbe is internationally renowned for its populations of the king cobra (*Ophiophagus hannah*), and its herpetofauna also includes Malabar pit vipers (*Craspedocephalus malabaricus*), vine snakes (*Ahaetulla* spp.), shieldtail snakes, skinks, geckos, and numerous endemic amphibians such as night frogs (*Nyctibatrachus* spp.).

The avifauna of the region is equally diverse and includes rainforest specialists such as the Asian fairy-bluebird (*Irena puella*), little spiderhunter (*Arachnothera longirostra*), crimson-backed sunbird (*Leptocoma minima*), Asian paradise flycatcher (*Terpsiphone paradisi*), Malabar trogon (*Harpactes fasciatus*), hornbills, laughingthrushes, drongos, and a variety of insectivorous and frugivorous birds. Freshwater streams and riparian habitats support a rich

diversity of endemic fishes, including several species of barbs, loaches, danios, and other taxa characteristic of Western Ghats stream ecosystems.

The broader landscape is a mosaic of evergreen forest fragments interspersed with areca nut plantations, banana cultivation, grasslands, paddy fields, and other agroforestry systems. This heterogeneity creates a gradient of natural and human-modified habitats that differ in vegetation structure, canopy cover, litter depth, microclimate, and resource availability. Such variation provides an excellent opportunity to examine patterns of ant diversity, behaviour, and resource use across contrasting habitat types. The study was conducted across forest patches, grasslands, and areca plantations, representing the dominant habitat types within the landscape.

Agumbe was selected as the study landscape owing to its location within the biodiversity-rich central Western Ghats and its mosaic of natural and human-modified habitats. Unlike many ecological studies conducted within protected areas, this study focuses on a non-protected landscape comprising forest fragments, grasslands, and agroforestry systems. These landscapes remain relatively understudied despite their importance in supporting biodiversity and maintaining ecological connectivity across the Western Ghats. While considerable research has been conducted on the region's flora, amphibians, reptiles, birds, and mammals, information on ant diversity, behaviour, and resource utilization remains limited. This makes Agumbe an ideal landscape for investigating patterns of ant diversity, behaviour, and resource selection within a tropical rainforest ecosystem.

10 Materials and Methods

10.1 Field and Analytical Methods

10.1.1 Objective 1: Ant Diversity, Morphometrics, and Behavioural Ecology

10.1.1.1 Study Design and Ant Sampling

Field surveys were conducted across four habitat types: Forest Patch, Grassland, Areca Plantation 1, and Areca Plantation 2. Areca plantation 1 is heterogeneous, with a mix of Areca palms, plantains, and coffee, among other plants, and is farther from the stream end. Areca Plantation 2 is a monoculture of Areca palms, where the stream ends and widens.

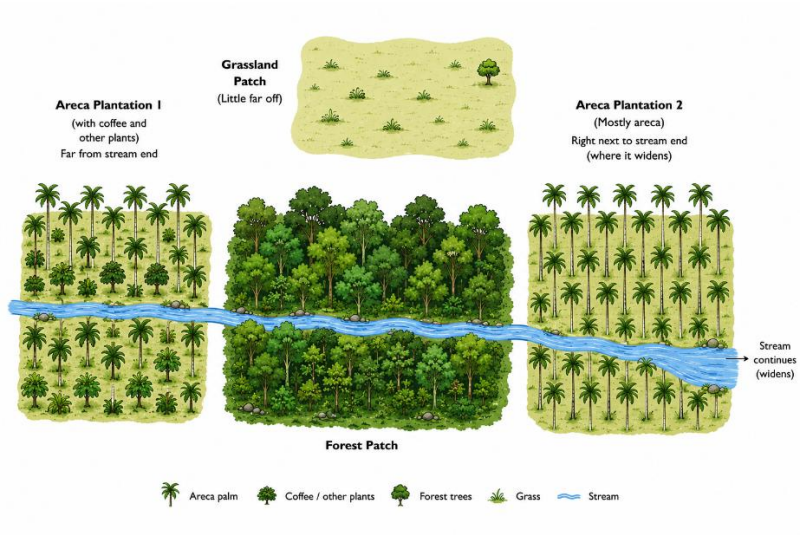


Figure 3. Pictorial representation of the Study Area Layout created using Biorender.

A total of 40 sampling sites were established, with ten sites located within each habitat type. Sites were surveyed repeatedly across three sampling rounds between December 2025 and March 2026. Therefore, 30 samples within each habitat type, accounting for a total sample size of 120.

Each sampling site consisted of a 10 × 10 m plot. Within each plot, four to five 1 × 1 m subplots were established for pitfall trapping. Five pitfall traps were installed within each subplot, with one trap placed at the centre and four positioned at the corners. Pitfall traps

were deployed in the morning and left active for approximately 24 hours before being collected the following morning.

Ants were sampled primarily through pitfall traps, active hand collection and visual encounter surveys. Multiple methods were used because different sampling techniques capture different components of ant communities, and combining methods generally provides a more complete assessment of species diversity than any single method alone (Romero & Jaffé, 1989; Bestelmeyer et al., 2000). Pitfall traps are effective for sampling active ground-dwelling ants, while hand collection and visual searches allow targeted sampling of species occupying leaf litter, fallen logs, vegetation, rock crevices, nests, and other microhabitats that may be underrepresented in pitfall samples (Agosti et al., 2000; Bestelmeyer et al., 2000). Active hand collection and visual encounter surveys were conducted at each site for one hour during each sampling round. Searches were conducted during both daytime and nighttime periods to maximise detection of species with different activity patterns. Search efforts focused on leaf litter, fallen logs, soil surfaces, vegetation, rock crevices, and other potential nesting and foraging microhabitats. Comparable search effort was maintained across all sites and habitat types throughout the study.

For each observation, species identity, habitat type, site information, and behavioural notes were recorded. Voucher specimens were collected for identification and photographic documentation.

Abundance estimates presented in this study represent the total number of individuals recorded across pitfall trapping, hand collection, and visual encounter surveys. As different sampling methods vary in their effectiveness for detecting particular taxa and behaviours, abundance values should be interpreted as relative measures of occurrence and activity rather than direct estimates of population size.

10.1.1.2 Species Identification

Collected specimens were sorted to morphospecies and identified using available taxonomic keys, reference collections, online databases, and expert consultation where required. Representative specimens were photographed and curated for subsequent verification.

Specimens were examined using a **Leica M125 C stereomicroscope** equipped with a **Leica MC190 HD camera** and a **Leica M205 A stereomicroscope** equipped with a **Flexacam C3 camera**. High-resolution images were captured for specimen documentation, morphological examination, and taxonomic verification. Identifications were made to the lowest possible taxonomic level, with most specimens identified to species level and others assigned to morphospecies where definitive identification was not possible.Taxonomic determinations of difficult taxa were verified by Paul Antony. Representative specimens were photographed, curated, and deposited in the National Centre for Biological Sciences (NCBS) National Repository, Bengaluru, with additional voucher specimens retained in the Wildlife Institute of India (WII) National Repository, Dehradun, to facilitate future taxonomic verification and reference.

10.1.1.3 Diversity Analysis

Species richness, abundance, Shannon diversity, Simpson diversity, and Pielou's evenness were calculated for the entire dataset and for each habitat type. Species accumulation curves and richness estimators (Chao1 and ACE) were used to assess sampling completeness.

Differences in species richness and diversity among habitat types and stream categories were evaluated using ANOVA and Kruskal–Wallis tests. Generalized Linear Models (GLMs) with a Poisson error distribution were used to examine the effects of habitat type, stream position, and their combined influence on species richness and abundance.

Community composition was examined using Non-metric Multidimensional Scaling (NMDS) based on Bray–Curtis dissimilarities. Permutational Multivariate Analysis of Variance (PERMANOVA) was used to test for differences in species composition among habitat types and stream categories. Indicator Species Analysis (IndVal) was performed to identify species significantly associated with particular habitat types.

10.1.1.4 Morphometric and Functional Trait Analysis

Focus-stacked images of selected specimens were captured using a stereomicroscope imaging system. Morphometric measurements were obtained in ImageJ software. Measurements included standard body dimensions relevant to body size, locomotion, and resource utilisation. Multiple individuals of the ten potentially undescribed species were measured due to lack of time.

10.1.1.5 Behavioural Observations

Behavioural observations were recorded opportunistically during field surveys and supplemented species occurrence records. Observed behaviours were classified into predefined categories and compiled into an ethogram. These records were used descriptively to document natural history observations, including foraging modes, recruitment strategies, resource use, nesting activities, and defensive behaviours exhibited by different species. As behavioural observations were not collected using a standardized sampling protocol, they were interpreted qualitatively and were not used to compare behavioural frequencies or rates among habitat types.

10.1.2 Objective 2: Resource Selection Experiment in *Trichomyrmex*

10.1.2.1 Experimental Design

Natural foraging trails of *Trichomyrmex* colonies were selected for the experiment. Resource selection experiments were conducted on 10 naturally occurring Trichomyrmex colonies. Each colony was tested repeatedly, with six experimental trials conducted per colony. Because multiple observations originated from the same colony, colony identity was retained as a random effect in mixed-effects analyses to account for repeated measures and avoid pseudoreplication. A total of 65 foraging events, including original observations and replicate observations across multiple sampling days, were recorded. Three food resources differing in physical texture were offered simultaneously along each foraging trail: sugar (rough texture), rice (medium rough/smooth texture), and seeds (smooth texture). Since each foraging event was exposed to all three resources, the study followed a repeated-measures design.

Data were collected using a pre-designed field form created in ODK Collect, and entries were automatically stored in linked Google Sheets for data management and analysis.

10.1.2.2 Variables Recorded

The response variable measured was food consumption (g) for each resource. Predictor variables included resource type (Sugar, Rice, and Seeds), resource texture (rough, medium rough/smooth, and smooth), and colony identity. Environmental variables such as temperature, humidity, and competitor abundance were also recorded where applicable.

10.1.2.3 Statistical Analysis

Descriptive statistics (mean ± standard deviation) were calculated for each resource type. Differences in food consumption among resources were analysed using a Friedman rank-sum test because the same colonies were repeatedly exposed to all treatments. Pairwise Wilcoxon signed-rank tests with Benjamini–Hochberg correction were subsequently used to identify significant differences between resource pairs while controlling for multiple comparisons.

To account for variation among colonies, a linear mixed-effects model was fitted with resource type as a fixed effect and colony identity as a random effect. This analysis was used to evaluate whether resource type significantly influenced food consumption after accounting for differences among colonies.

Boxplots were used to visualise variation in food consumption among resource types. Skewness and kurtosis were calculated to describe the distribution of consumption values and evaluate the presence of asymmetry or extreme observations in the dataset.

11 Results

11.1 Objective 1.1

A total of **75 ant species** were recorded from **40 sampling sites** across the study area, resulting in **423 occurrence records** and **10,284 individuals**. A total of **116 sampling events** yielded ant observations across areca plantations, forest patches, and grassland habitats **out of 120 sampling events**. Sampling generated data on species richness, abundance, community composition, behaviour, morphometric variation, and resource utilisation. Diversity indices, community analyses, behavioural observations, and experimental results are presented below according to the objectives of the study. In addition to documenting patterns of diversity and habitat use, the survey also yielded several notable taxonomic findings, including potentially undescribed species, new distribution records, and observations of morphological variation within selected taxa.

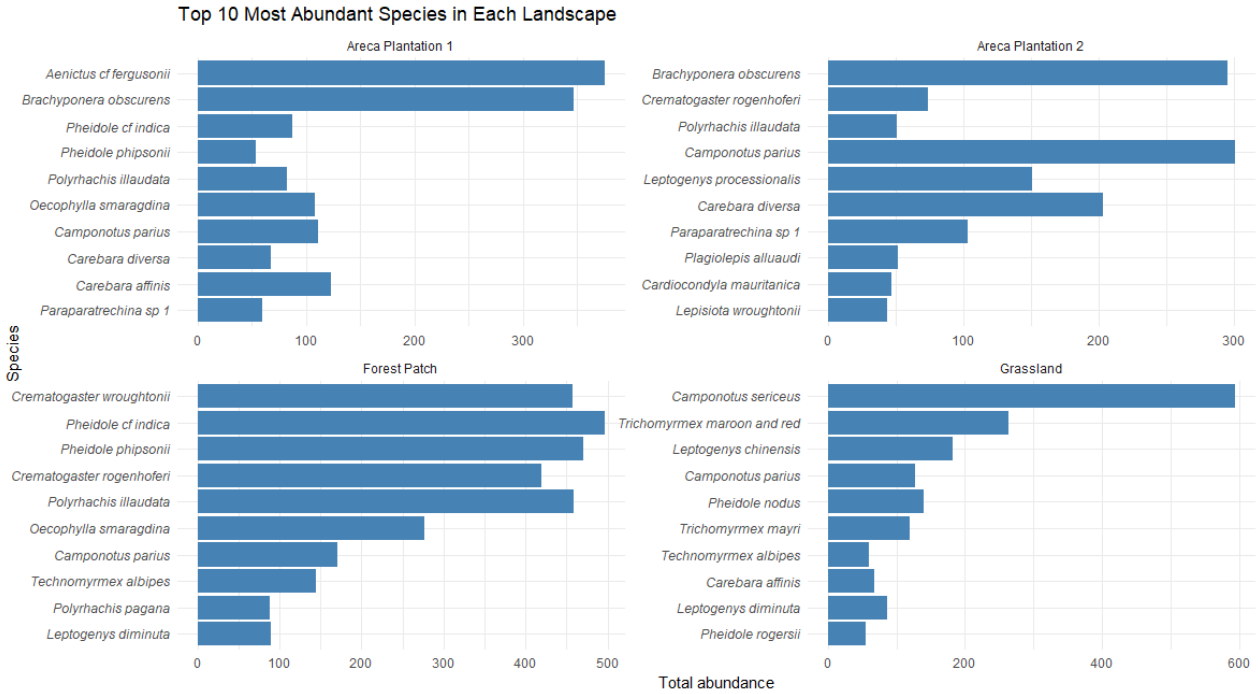


Figure 4. Top 10 most abundant species in each landscape, Areca Plantation 1 and 2, Forest Patch and Grassland

Species dominance patterns differed among landscapes. In Areca Plantation 1, the most abundant species were *Aenictus cf. fergusonii*, *Brachyponera obscurens*, and *Pheidole cf. indica*. Areca Plantation 2 was dominated by *Brachyponera obscurens*, followed by *Carebara diversa* and *Leptogenys processionalis*. Forest patches were characterized by high abundances of *Pheidole cf. indica*, *Crematogaster wroughtonii*, *Crematogaster rogenhoferi*, and *Polyrhachis illaudata*. In grasslands, *Camponotus sericeus* was the dominant species, followed by *Trichomyrmex* spp. and *Leptogenys chinensis*. These results indicate that different habitats supported distinct dominant ant assemblages.

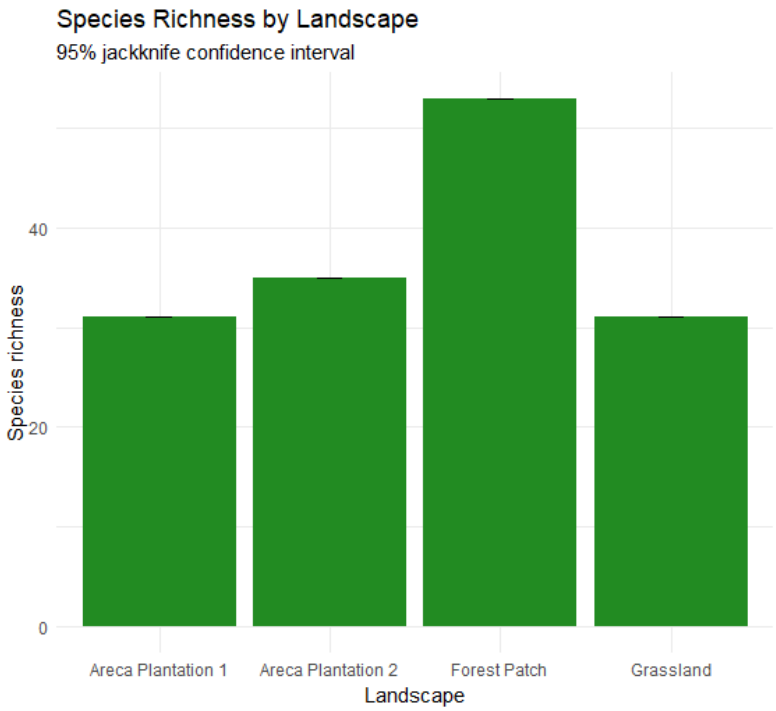


Figure 5. Observed ant species richness (Gamma diversity measure) is shown for Areca Plantation 1, Areca Plantation 2, Forest Patch, and Grassland, each represented by 10 sampling plots. (Richness was calculated from pooled species occurrence records within each landscape, and error bars represent 95% jackknife confidence intervals around the landscape-level richness estimate.)

Species richness and diversity varied among landscape types under a standardized sampling design. Forest patches supported the highest richness (**53 species**) and highest Shannon diversity (**3.13**), followed by Areca Plantation 2 (**35 species**, Shannon = 2.82), Areca Plantation 1 (**31 species**, Shannon = 2.81), and Grassland (**31 species**, Shannon = 2.72). Confidence intervals estimated through jackknife resampling of sampling events indicated that these diversity estimates were relatively stable across habitats. Forest patches consistently exhibited higher diversity than the other habitat types, suggesting that they support more diverse ant communities within the study landscape. (Fig 5).

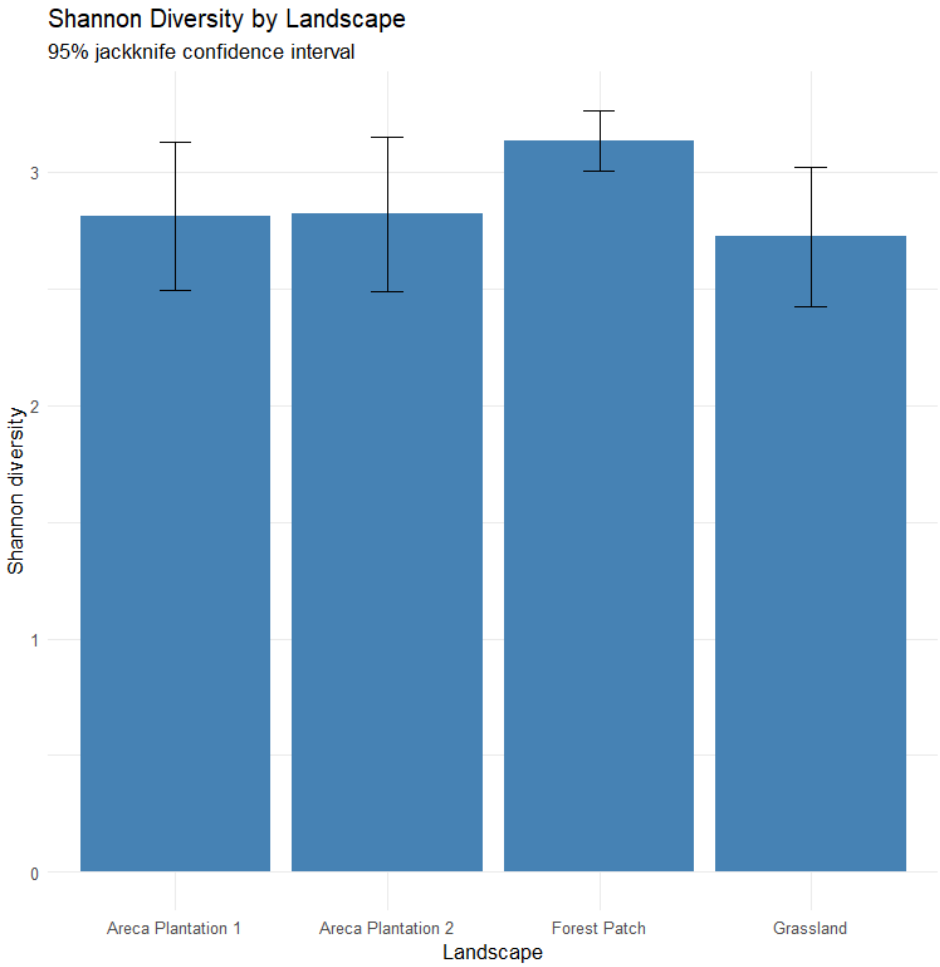


Figure 6**.** Shannon diversity (alpha diversity measure) of ant communities across four landscape types in Agumbe, Karnataka. Shannon diversity is shown for Areca Plantation 1, Areca Plantation 2, Forest Patch, and Grassland, each represented by 10 sampling plots. (Diversity was calculated from pooled ant abundance data within each landscape, and error bars represent 95% jackknife confidence intervals around the landscape-level Shannon diversity estimate.)

Overall diversity was high, with a Shannon diversity index of **3.59** (95% jackknife CI: 3.44–3.73) (Fig 6), Simpson diversity of **0.96** (95% CI: 0.95–0.97), and Pielou's evenness of **0.83**, indicating a relatively even distribution of individuals among species.

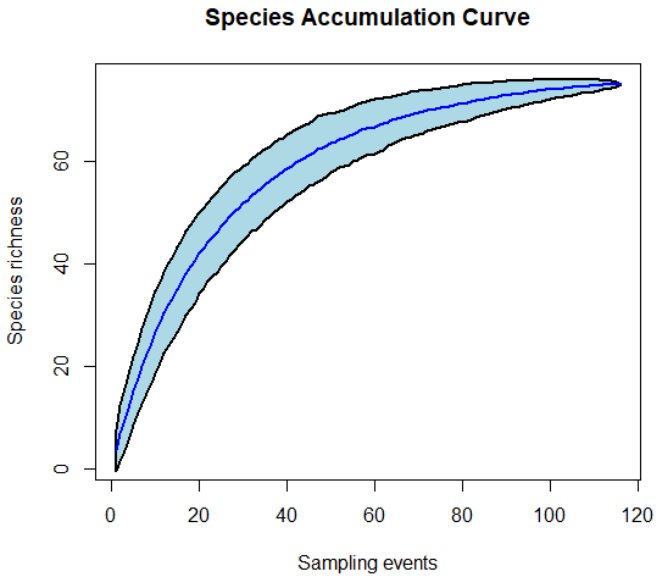


Figure 7. Species Accumulation Curves for the landscape

The overall species accumulation curve (Fig 7) showed that fewer new species were recorded as sampling increased. The curve began to level off after reaching 75 species, suggesting that most species were recorded during the study and that further sampling would likely add only a few new species.

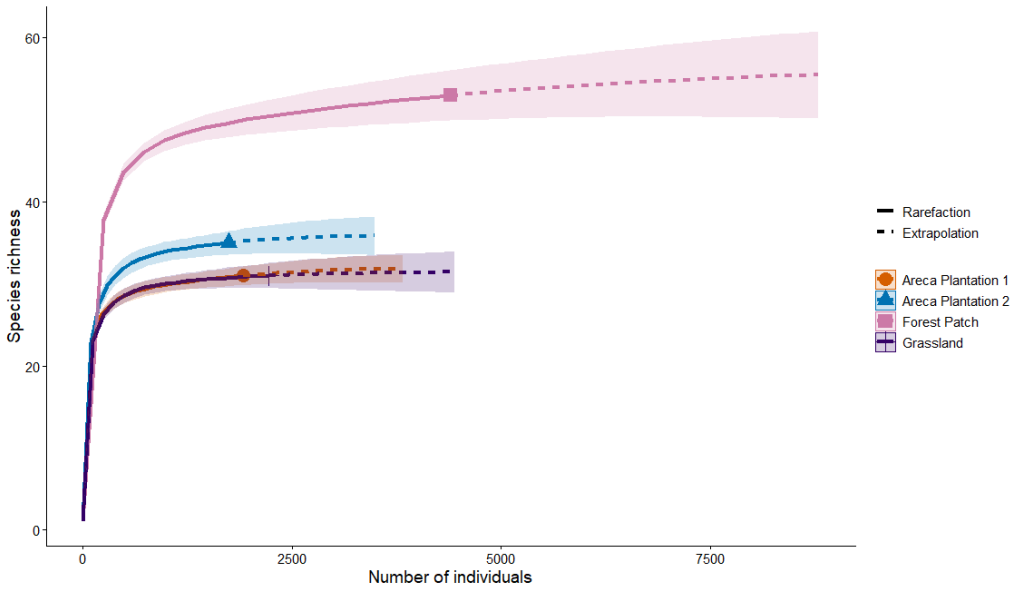


Figure 8. Rarefaction curves for each habitat

Forest patches accumulated species more rapidly and attained the highest richness (Fig 8), reaching 53 observed species, whereas both areca plantations and grasslands supported lower richness values of 31–35 species. The forest patch curve approached an asymptote most closely, suggesting that most species present in this habitat were captured by the sampling effort. In contrast, the curves for Areca Plantation 1, Areca Plantation 2, and Grassland continued to rise slightly towards the end of sampling and did not fully reach an asymptote, indicating that additional sampling would likely detect a small number of additional rare species.

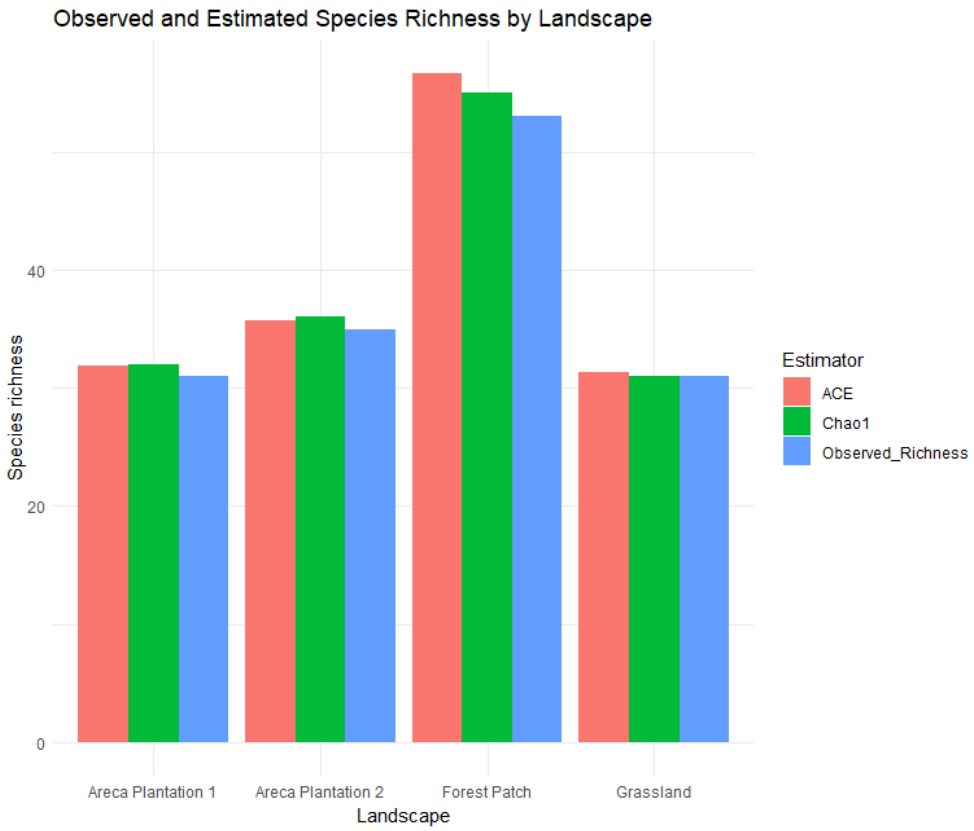


Figure 9. Observed species richness and richness estimates (Chao1 and ACE) for ant communities across four landscape types.

Estimated richness values were only marginally higher than observed richness across all habitat types, suggesting a high degree of sampling completeness within the sampling period

and methods employed in this study. Forest patches supported the highest observed and estimated richness, whereas both areca plantations and grassland exhibited lower richness values.

Richness estimators produced values only slightly higher than the observed richness in all habitats (Fig. 7). In Areca Plantation 1, observed richness was 31 species, while Chao1 and ACE estimated approximately 32 species. Areca Plantation 2 had an observed richness of 35 species, with Chao1 and ACE estimates of 36 and 35.8 species, respectively. Forest patches exhibited the highest estimated richness, with 53 observed species, a Chao1 estimate of 55 species, and an ACE estimate of 56.7 species. Grassland showed little difference between observed and estimated richness, with 31 observed species and estimated richness values of approximately 31–31.3 species. The close agreement between observed and estimated richness across all landscapes suggests that sampling captured the majority of species present, although some additional rare species may remain undetected, particularly in forest patches.

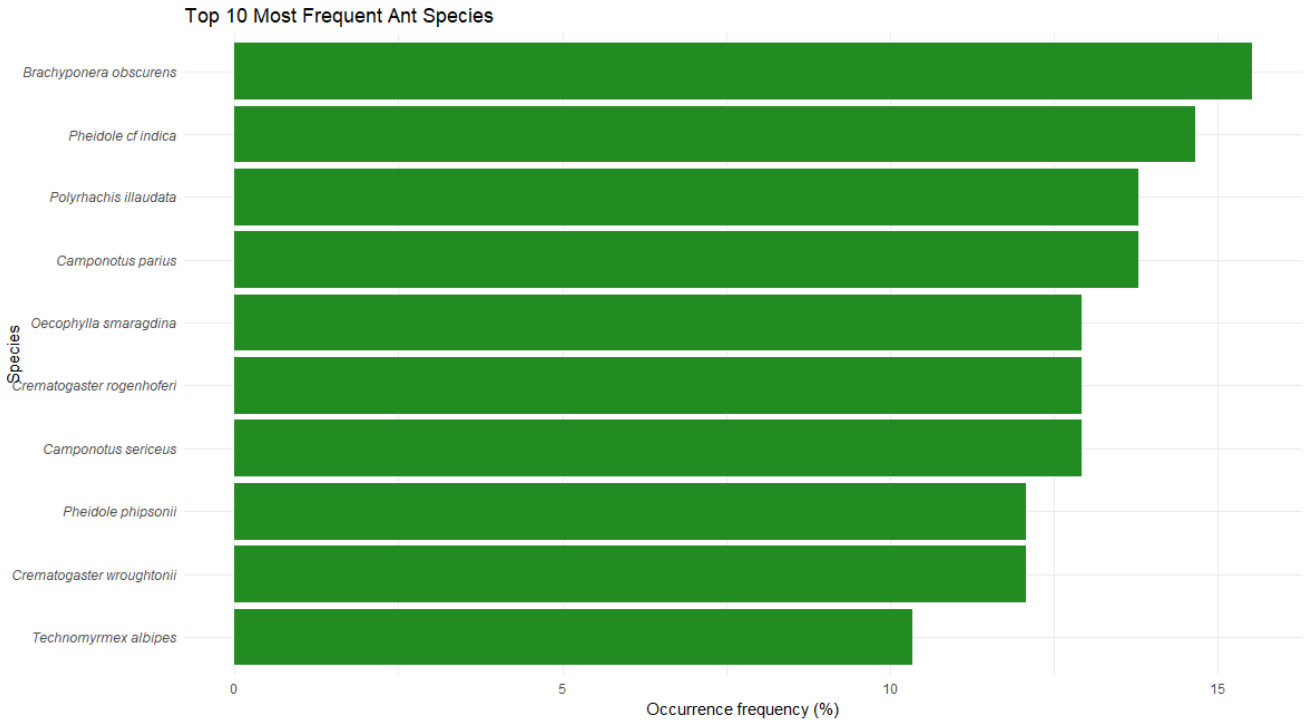


Figure 10. The top 10 most frequent ant species in the whole study area (Occurence frequency in percentage in 116 sample events)

Occurrence frequency varied among species, with *Brachyponera obscurens* recording the highest frequency (15.5%), followed by *Pheidole cf. indica* (14.6%) and *Polyrhachis illaudata* (13.8%). The remaining species showed frequencies between 10–14%, indicating that these taxa were among the most widespread ants recorded during the study.

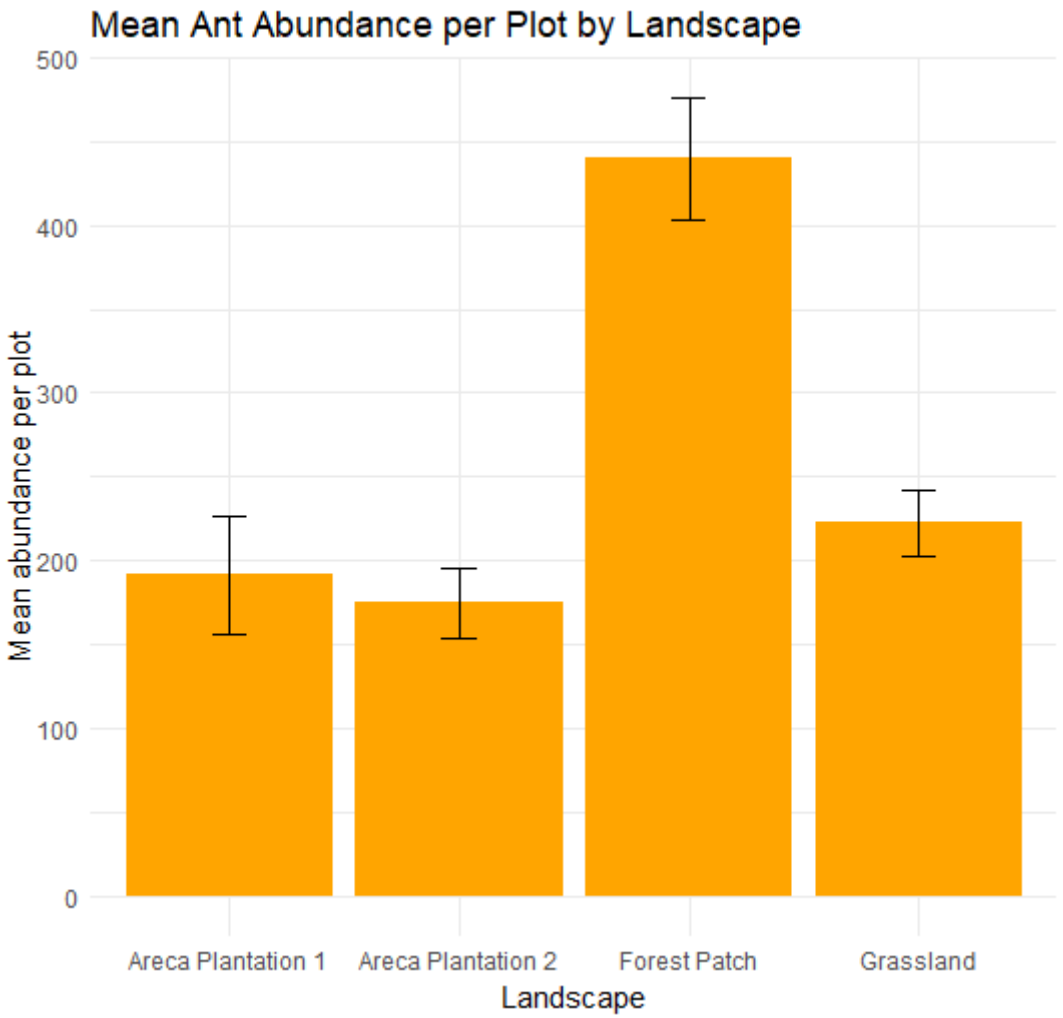


Figure 11. Mean ant abundance per plot varied among landscapes.

Forest patches had the highest mean abundance per plot (approximately 440 individuals), followed by grassland (approximately 220 individuals), Areca Plantation 1 (approximately 190 individuals), and Areca Plantation 2 (approximately 175 individuals). Error bars showed moderate variation among plots within each landscape. These results indicate that forest patches supported substantially greater numbers of ants than the other habitat types. Forest patches also showed the greatest total abundance (**4,397 individuals**) and the highest number of occurrence records (**195**), whereas Areca Plantation 1, Areca Plantation 2, and grassland supported **1,916**, **1,747**, and **2,224 individuals**, respectively.

Species richness differed significantly among landscape types (ANOVA: $F = 57.63$, $p < 0.001$). Tukey's HSD test indicated that Forest Patches had significantly higher richness than both Areca plantations and Grasslands, whereas differences among the latter three habitats were not significant. Similar patterns were observed for Shannon diversity (ANOVA: $F = 37.33$, $p < 0.001$). Kruskal-Wallis tests supported these findings for both richness and Shannon diversity ($p < 0.001$).

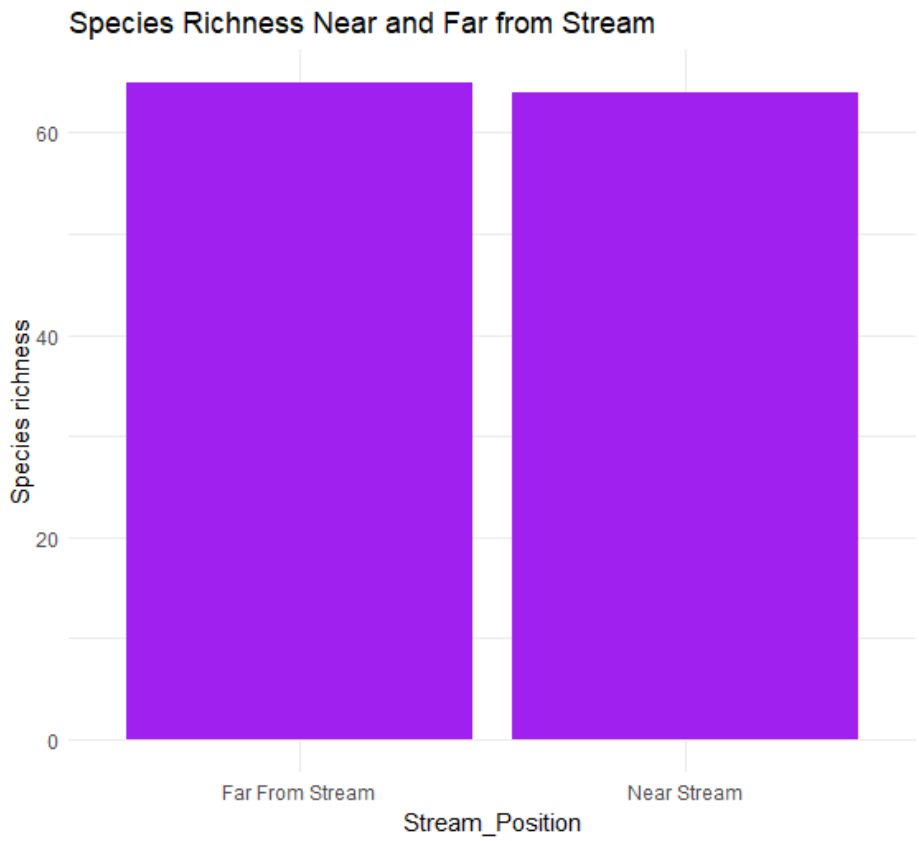


Figure 12. Species richness of ant communities at sites located near and far from streams in the study area.

In contrast, stream position had no significant effect on species richness (ANOVA: $p = 0.806$; Kruskal-Wallis: $p = 0.573$). Two-way ANOVA further showed that landscape type significantly influenced richness ($p < 0.001$), whereas stream position and the interaction between landscape and stream position were not significant.

Response Variable	**Landscape Effect**	**Stream Effect**	**Landscape + Stream Model**
Species Richness	<0.001 ***	0.776 ns	Landscape <0.001 ***, Stream 0.487 ns
Total Abundance	<0.001 ***	<0.001 ***	Landscape <0.001 ***, Stream <0.001 ***

Table 1. Results of generalized linear models examining the effects of landscape and stream proximity on ant species richness and total abundance. *(*** indicates significant, and ns indicates non-significant).*

GLM analyses indicated that landscape type significantly affected both species richness and total abundance of ants ($p < 0.001$). Stream position had no significant effect on species richness but significantly influenced total abundance ($p < 0.001$). These results suggest that habitat type was the main driver of ant diversity patterns across the study area, while stream position primarily affected the number of individuals recorded.

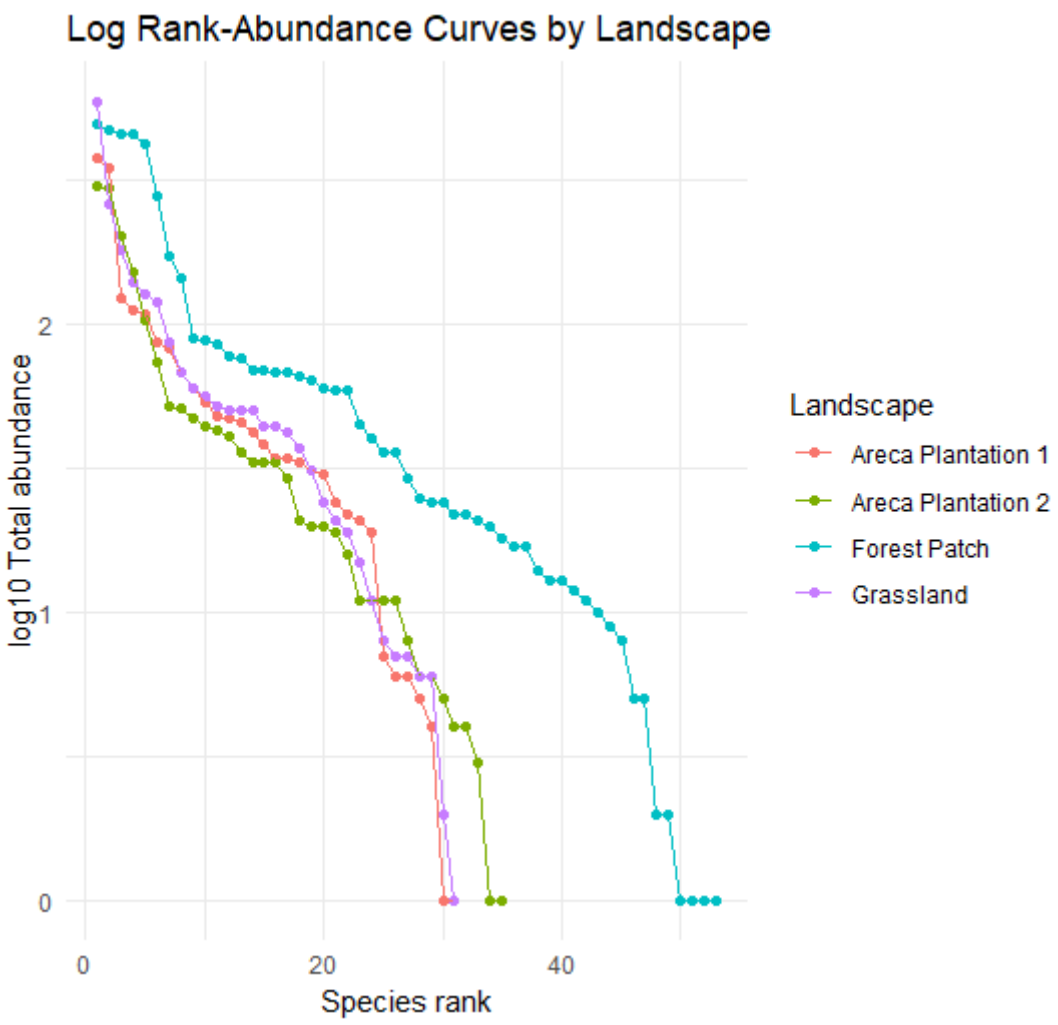


Figure 13. Log rank–abundance curves of ant communities across landscapes, showing differences in species richness, dominance, and evenness among habitat types

Log rank-abundance curves revealed differences in community structure among landscapes (Fig. 13). Forest patches exhibited the longest curve and greatest number of ranked species, indicating higher species richness. The forest curve also showed a more gradual decline in abundance with rank, suggesting relatively higher evenness compared to other habitats. In contrast, the curves for both areca plantations and grassland declined more steeply, indicating stronger dominance by a smaller number of species and lower overall richness. Forest patches

therefore supported both a greater number of species and a more even distribution of individuals among species.

The abundance distribution was strongly right-skewed (Skewness = 8.85) and highly leptokurtic (Kurtosis = 135.78). Most records consisted of low to moderate abundance values, while a few observations contained exceptionally large numbers of individuals. This pattern was evident in the histogram, where most abundance values were clustered below 60 individuals and a single extreme value represented the large *Aenictus* swarm.

Among habitats, Areca Plantation 1 showed the highest skewness (6.65) and kurtosis (50.3), indicating stronger dominance by a few highly abundant species compared with other habitats.

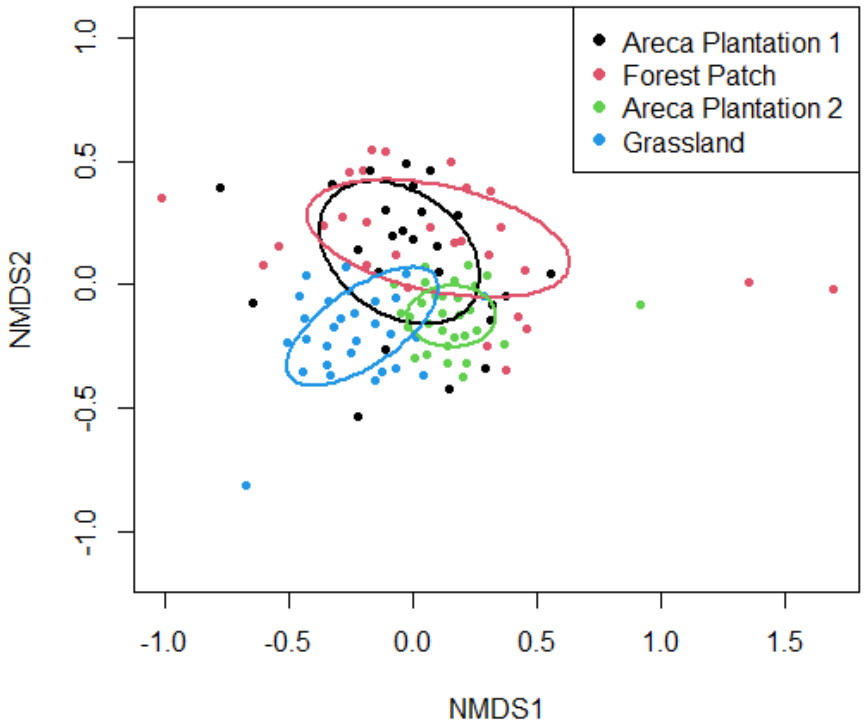


Figure 14. Non-metric multidimensional scaling (NMDS) ordination of ant community composition across the four landscape types. Each point represents a sampling site, and

ellipses indicate the dispersion of communities within each landscape. Partial overlap among groups suggests similarities in species composition, while differences in cluster positions indicate variation in ant community structure among landscapes.

The NMDS ordination produced a low stress value (**0.094**), indicating a reliable representation of community dissimilarities. Although the habitat polygons showed some overlap, Forest Patch samples occupied a broader ordination space and tended to separate from plantation and grassland samples, suggesting differences in community composition.

PERMANOVA confirmed that landscape type significantly affected ant community composition ($R^2 = 0.140$, $F = 6.10$, $p = 0.001$). In contrast, stream position did not significantly influence community composition ($R^2 = 0.009$, $p = 0.406$). When both variables were included in the model, the overall effect remained significant ($R^2 = 0.15$, $p = 0.001$), with landscape being the primary driver.

Indicator Species Analysis identified 27 species that were significantly associated with particular habitat types. Forest Patch supported the highest number of indicator species (16), including *Pheidole phipsonii*, *Crematogaster wroughtonii*, *Polyrhachis illaudata*, *Pheidole* cf. *indica*, and *Crematogaster rogenhoferi*. Grassland had four indicator species: *Camponotus sericeus*, *Trichomyrmex* maroon and red morphotype, *Leptogenys chinensis*, and *Trichomyrmex* black morphotype. Areca Plantation 1 had one indicator species, *Plagiolepis jerdonii*, while Areca Plantation 2 had two, *Carebara diversa* and *Plagiolepis alluaudi*. *Brachyponera obscurens* and *Leptogenys processionalis* were associated with both areca plantation habitats. These results indicate habitat associations within the study landscape rather than strict habitat specialization.

11.2 Objective 1.2

Species	**TL (mm)**	**HL (mm)**	**HW (mm)**	**EL (mm)**	**WL (mm)**
Paraparatrechina sp. 1	1.8	0.4	0.32	0.08	0.5
Paraparatrechina sp. 2	2	0.44	0.35	0.09	0.56
Tapinoma sp.	2.3	0.5	0.4	0.1	0.65
Tetramorium sp.	2.8	0.62	0.58	0.12	0.82
Aenictus sp.	3.5	0.75	0.62	0.04	1
Dilobocondyla sp.	4.2	0.95	0.88	0.18	1.25
Polyrhachis sp. 1	4.8	1.02	0.92	0.22	1.45
Polyrhachis sp. 2	5.5	1.15	1	0.25	1.62
Camponotus sp.	6.2	1.4	1.22	0.3	2
Camponotus (Tanaemyrmex group)	7	1.6	1.35	0.35	2.3

Table 2. Morphometric measurements of representative ant species collected from the Agumbe landscape. Measurements include total length (TL), head length (HL), head width (HW), eye length (EL), and Weber's length (WL), illustrating variation in body size and morphology among genera.

Morphometric measurements revealed substantial variation in body size and morphology among the selected ant taxa (Table 2). Total body length ranged from 1.8 mm in *Paraparatrechina* sp. 1 to 7.0 mm in *Camponotus* (Tanaemyrmex group), representing nearly a four-fold difference in size. Head length and head width generally increased with body size, with the largest values observed in *Camponotus* species and the smallest in *Paraparatrechina*. Eye length also varied among genera, with *Aenictus* exhibiting notably small eyes relative to body size, whereas *Polyrhachis* and *Camponotus* possessed comparatively larger eyes. Weber's length, a measure of mesosoma size, followed a similar trend and ranged from 0.50 mm to 2.30 mm. Overall, the dataset captures a broad range of functional morphologies, from small-bodied, slender ants to larger and more robust species, highlighting the morphological diversity present within the ant assemblage.

11.3 Objective 1.3

Behavioural observations showed different behaviours among ant species across the study area. The behaviours recorded included foraging, feeding, social interactions, nest-related activities, defence, and movement behaviours.

Behaviour_Category	Specific_Behaviour	Operational_Definition	Example_Taxa
Foraging	Solitary foraging	Single worker searches independently without visible recruitment	*Camponotus, Brachypena, Harpegnathos*
	Group foraging	Several workers forage together without a strong trail	*Pheidole, Crematogaster*
	Mass recruitment	Large numbers rapidly recruited to food or bait	*Pheidole, Crematogaster*
	Trail following	Workers follow a visible/chemical trail	*Technomyrmex, Lasiius, Paraparatrechina*
	Scouting	Fast exploratory searching in a new area	*Myrmecina, Tapinoma*
	Seed collection	Workers carry seeds or plant fragments	*Pheidole, Tetramorium, Trichomyrmex*
	Predatory hunting	Workers actively search for, attack, or carry prey	*Lasiocampis, Anochetus, Harpegnathos, Strumigenys*
	Swarming/recolonisation	Coordinated movement of many workers to a nest or new location	*Formicinae, Leptothorax, polycottonis*
Feeding	Honeydew collection	Workers attend hemipterans or collect sugary exudates	*Camponotus, Technomyrmex, Crematogaster*
	Scavenging	Workers feed on dead insects or organic remains	*Messor, Iridomyrmex, Carebara, Tetramorium*
	Social interaction	Workers exchange mouthparts or regurgitate food items	*Camponotus, Pheidole, Cataglyphis, Technomyrmex*
	Brood transport	Workers carry larvae, pupae, or brood items	*Carebara, Pheidole, Camponotus, Technomyrmex*
Nest behaviour	Nest maintenance	Excavation, soil movement, debris removal, nest repair	*Tetramorium, Pheidole, Trichomyrmex*
Defence	Aggressive display	Raised posture, open mandibles, territorial response	*Oecophylla, Anochetus, Harpegnathos*
Movement	Climbing vegetation	Movement on trunk, branch, leaf, shrub, or canopy	*Polyrhachis, Oecophylla, Tetraponera*
	Underground searching	Movement beneath rocks or stones	*Aenictus, Strumigenys*

Figure 15. Ethogram of recorded behaviours of ant species

Foraging behaviours were the most commonly observed. Solitary foraging, trail following, mass recruitment, and predatory hunting formed a large proportion of the observations. Predatory behaviour was mainly observed in *Leptogenys* spp., *Anochetus daedalus*, *Harpegnathos saltator*, and *Brachyponera obscurens*. *Aenictus cf. fergusonii* and *Leptogenys processionalis* showed collective movement in the form of swarm or processional raids.

Feeding-related behaviours included honeydew collection and scavenging. Honeydew collection was commonly observed in *Crematogaster*, *Camponotus*, and *Technomyrmex* species, while scavenging behaviour was observed mainly in *Meranoplus bicolor*, *Carebara*, and several ground-dwelling taxa.

Seed collection behaviour was observed in *Trichomyrmex* and *Pheidole* species, especially in grassland and open habitats. Brood transport was recorded in *Carebara*, *Camponotus*, and *Technomyrmex*, while *Trichomyrmex* frequently showed nest maintenance behaviour.

Arboreal species such as *Polyrhachis*, *Oecophylla smaragdina*, and *Tetraponera rufonigra* were commonly associated with climbing and vegetation-based movement, whereas litter-dwelling species such as *Strumigenys mutica* and *Parasycia cf. aitkenii* were associated with litter-based movement and searching behaviour.

11.4 Objective 2

A total of 65 food preference experiments were conducted on *Trichomyrmex* colonies. Mean food consumption differed among the three resources offered. Sugar showed the highest consumption (3.62 ± 1.52 g), followed by rice (3.08 ± 1.55 g), while seeds showed the lowest consumption (2.37 ± 1.46 g).

Food consumption differed significantly among the three food resources offered to *Trichomyrmex* colonies (Friedman rank-sum test: $\chi^2 = 32.43$, df = 2, $p < 0.001$). Pairwise Wilcoxon signed-rank tests with Benjamini–Hochberg correction revealed significant differences between all resource pairs. Sugar consumption differed significantly from rice ($p = 0.00093$) and seeds ($p < 0.001$), while rice consumption also differed significantly from seeds ($p = 0.00290$). These results indicate a clear preference hierarchy:

Sugar > Rice > Seeds

To account for variation among colonies, a linear mixed-effects model was fitted with resource type as a fixed effect and colony identity as a random effect. The model showed a significant effect of resource type on food consumption ($F = 3.91$, $p = 0.031$). Relative to sugar, consumption was lower for rice (estimate = −0.43) and substantially lower for seeds

(estimate = −1.57). These results support the findings of the Friedman and Wilcoxon tests and indicate that the observed preference pattern was consistent across colonies.

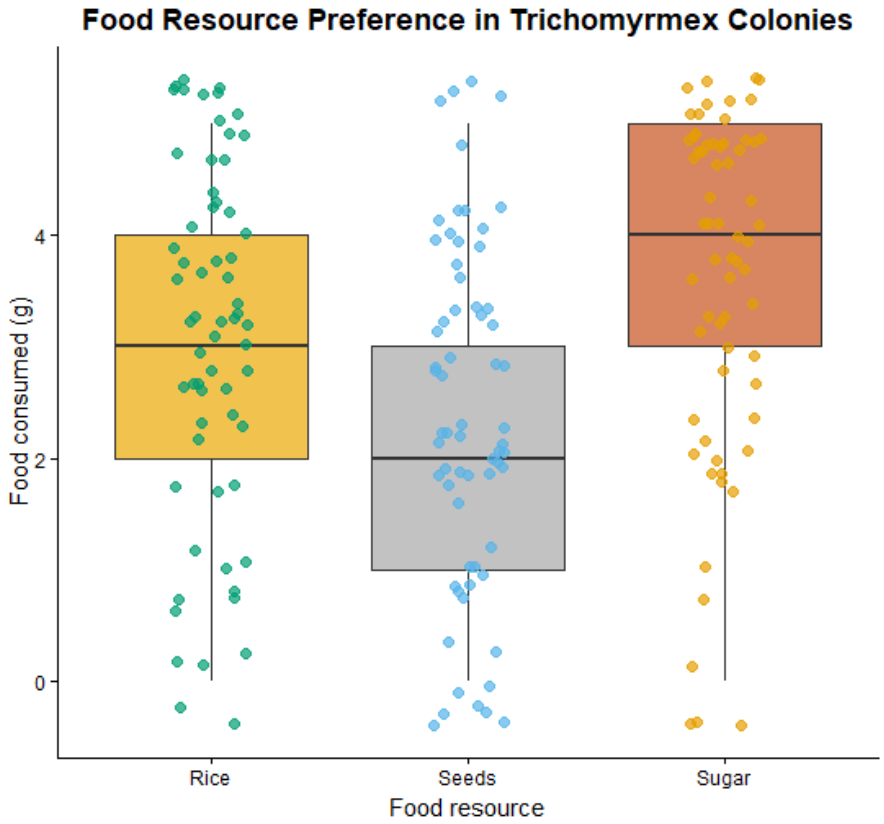


Figure 16. Food consumption by *Trichomyrmex* colonies across three food resources differing in physical texture.

Sugar (rough texture) showed the highest consumption, followed by rice (medium rough/smooth texture) and seeds (smooth texture). Boxes represent interquartile ranges, horizontal lines indicate median values, whiskers represent the range of observations, and points represent individual experimental observations. The distributions show a clear preference hierarchy of Sugar > Rice > Seeds, with relatively symmetrical consumption patterns and no strong outliers, as indicated by low skewness and kurtosis values.

The boxplot showed the highest median consumption for sugar, intermediate consumption for rice, and the lowest consumption for seeds. Sugar and rice showed some overlap in consumption values, whereas seed consumption was generally lower across colonies.

Overall consumption values exhibited slight negative skewness (Skewness = −0.38) and low kurtosis (Kurtosis = 2.10). Resource-specific skewness values ranged from −0.90 for sugar to 0.004 for seeds, while kurtosis ranged from 2.18 to 2.82. These values indicate that consumption data were relatively symmetrical and lacked strong outliers or extreme tails.

12 Discussion

The present study provides a detailed assessment of ant diversity, community composition, behaviour, functional traits, and resource selection in a mosaic landscape of forests, areca plantations, and grasslands in and around Agumbe, Central Western Ghats. A total of 75 ant species were recorded during the survey, reflecting the high biodiversity of the region and the ecological importance of the habitats sampled. The results revealed clear differences in diversity and community composition among habitats, as well as substantial variation in behavioural strategies and resource use among species.

Ants are among the most ecologically important groups of insects in tropical ecosystems, where they contribute to processes such as predation, scavenging, nutrient cycling, seed dispersal, soil turnover, and mutualistic interactions with other organisms. Because ant communities respond strongly to changes in habitat structure and environmental conditions, they are widely used as indicators of ecosystem health and habitat quality. The patterns observed in the present study therefore provide valuable insights into both the ecological functioning of the Agumbe landscape and the factors influencing ant community organisation.

In addition to documenting patterns of diversity and behaviour, the study also yielded several important taxonomic observations, including potentially undescribed species, new distribution records, and previously undocumented morphological variation. These findings demonstrate that significant gaps remain in our understanding of ant diversity in the Western Ghats and highlight the importance of continued surveys in this globally important biodiversity hotspot.

Objective 1: Ant Diversity, Functional Traits, and Behavioural Ecology

The ant community recorded in the present study showed high richness and diversity across the sampled habitats. The relatively high Shannon diversity and Simpson values indicate that the community was composed of many species with no extreme dominance by a few taxa. The Pielou evenness value further suggests that individuals were distributed relatively evenly across species, a pattern commonly associated with structurally complex tropical ecosystems.

Forest patches supported the highest richness, abundance, and diversity among all habitats. They also contained the greatest number of occurrence records and indicator species. These patterns are likely linked to the greater habitat complexity present within forests, including deeper leaf litter, higher vegetation heterogeneity, greater nesting opportunities, and more stable microclimatic conditions. Similar patterns have been reported from other studies in the Western Ghats and tropical forests worldwide, where ant diversity is often highest in relatively undisturbed habitats and declines with increasing habitat simplification.

Species dominance patterns varied among landscapes, indicating that different habitats supported distinct ant assemblages. Forest patches were characterised by species such as *Pheidole cf. indica, Crematogaster wroughtonii, Crematogaster rogenhoferi,* and *Polyrhachis illaudata*, while areca plantations and grasslands were dominated by different sets of species. These differences likely reflect variation in habitat structure, resource availability, nesting

substrates, and microclimatic conditions among landscapes. The presence of habitat-specific dominant species suggests that different ant taxa respond differently to environmental conditions and contribute to the unique community structure of each habitat.

The species accumulation curves showed that most ant species present in the study area were successfully recorded. Forest patches accumulated species more quickly and had the highest richness, while areca plantations and grasslands supported fewer species. The slight increase in the curves towards the end of sampling suggests that a few rare species may still remain undetected. However, the close match between observed and estimated richness indicates that sampling was largely complete across all habitats.

Rank-abundance patterns also showed clear differences among habitats. Forest patches had more species and a more even distribution of individuals, while areca plantations and grasslands were dominated by a smaller number of species. Most species occurred in low numbers, whereas a few species were very abundant. This pattern was influenced by the large *Aenictus* swarm recorded during the survey, which contributed a very high number of individuals compared to most other observations.

Community analyses showed that habitat type had a stronger influence on ant communities than stream position. The NMDS ordination showed some overlap among habitats, but forest sites tended to separate from plantation and grassland sites, indicating differences in species composition. PERMANOVA confirmed that these differences among habitats were statistically significant. In contrast, stream position had little effect on species richness or community composition. This suggests that habitat structure, vegetation cover, leaf litter, and nesting opportunities may also play a role in shaping ant communities than proximity to streams. Some studies have found that streamside or riparian habitats support different ant communities because of higher moisture levels, greater vegetation complexity, and

differences in habitat quality (Zina,V. et al, 2021). However, no such pattern was detected in the present study. This may be because the Agumbe landscape remains humid throughout the year, resulting in relatively similar conditions near and away from streams. .

The GLM results showed that habitat type was the main factor affecting ant diversity in the study area. Forest patches supported higher species richness and abundance than the other habitats, highlighting the importance of forest habitats for maintaining diverse ant communities. The greater habitat complexity, availability of nesting sites, and variety of resources in forests likely support a larger number of species and individuals.

In contrast, stream position did not affect species richness, suggesting that the number of ant species present was influenced more by habitat type than by proximity to streams. This may be because the Agumbe landscape remains generally humid throughout the study area.

However, stream position did influence ant abundance. Although similar numbers of species occurred near and away from streams, the number of individuals differed between these locations. This suggests that stream proximity may affect ant activity or population size rather than species diversity. Overall, the results indicate that habitat type is the primary factor shaping ant communities in the landscape.

Indicator species analysis provided additional evidence for habitat-specific community structure. Forest patches supported the largest number of indicator species, including *Pheidole phipsonii, Crematogaster wroughtonii, Polyrhachis illaudata,* and *Crematogaster rogenhoferi*. Grasslands and areca plantations supported fewer indicator species, although several taxa showed strong associations with these habitats. Such species may serve as useful indicators of habitat condition and environmental change in future monitoring programmes.

The survey also produced several noteworthy taxonomic findings. Ten potentially undescribed species were documented during the study, including representatives of *Aenictus*,

the *Camponotus tanaemyrmex* group, an additional *Camponotus* species, *Dilobocondyla*, two species of *Paraparatrechina*, two species of *Polyrhachis*, *Tapinoma*, and *Tetramorium*. Recent taxonomic studies (Shakur & Bagchi, 2024; Mathew et al., 2022; Nayak et al., 2026) indicate that substantial undocumented ant diversity remains in both the Western and Eastern Ghats. In the Western Ghats, several new species of the army ant genus *Aenictus* have been described in recent years, including *Aenictus kodungallurensis*, *A. malakkaparensis*, and *A. kadalarensis* from Kerala. In the Eastern Ghats, two new species, *Aenictus chittoorensis* and *A. lankamallensis*, were recently described from Andhra Pradesh. The discovery of multiple potentially undescribed species during the present study is therefore consistent with recent findings and highlights the need for continued taxonomic surveys in the Ghats.

In addition to the potentially undescribed species, the survey resulted in the first record of *Strumigenys mutica* from Karnataka and the first state record of a *Paraparatrechina* morphospecies. These records extend the known distributions of these taxa and contribute valuable information to the growing understanding of ant biogeography in southern India. Such range extensions are important because many ant species remain poorly sampled, particularly in tropical forest landscapes where cryptic species are easily overlooked.

A particularly interesting observation was the occurrence of worker polymorphism in *Lepisiota wroughtonii*. Distinct worker size classes were observed within colonies, suggesting the presence of morphological differentiation that may be associated with division of labour or task specialization. Although worker polymorphism is well documented in several ant genera, it has rarely been reported for *Lepisiota*. Further studies examining colony structure, worker morphology, and task allocation may help determine whether this pattern represents a stable caste system or environmentally driven variation.

All voucher specimens collected during the study were curated, labelled, and deposited in a national repository to ensure their long-term preservation and availability for future taxonomic, ecological, and biogeographic research. The deposition of voucher material is particularly important for newly recorded and potentially undescribed taxa, as it provides a permanent reference for future verification and formal taxonomic study.

Together, these findings demonstrate that the ant fauna of the Agumbe landscape is both ecologically diverse and taxonomically significant. The combination of high species richness, distinct habitat-associated assemblages, new distribution records, and potentially undescribed taxa highlights the importance of conserving remnant forest habitats within the landscape and underscores the need for continued systematic surveys in the Western Ghats.

Objective 1.2: Morphometric Variation Among Selected Ant Species

The observed variation in morphometric traits among the selected ant species suggests potential differences in ecology, foraging behaviour, and habitat use. Smaller-bodied genera such as *Paraparatrechina*, *Tapinoma*, and *Tetramorium* may be better suited to exploiting small food resources and moving through confined microhabitats, whereas larger-bodied genera such as *Polyrhachis* and *Camponotus* may be capable of handling larger food items and travelling greater foraging distances. The relatively small eye size observed in *Aenictus* despite its larger body size is consistent with its predominantly subterranean and predatory lifestyle, where vision is likely less important than chemical communication. Variation in head dimensions may influence mandible function and resource handling, while differences in Weber's length reflect variation in overall body size and morphology. Although these observations suggest potential ecological differences among species, the present study did not directly test relationships between morphological traits and ecological performance.

Therefore, these interpretations should be regarded as hypotheses for future investigation rather than definitive evidence of functional differentiation.

Objective 1.3: Behavioural Ecology and Resource Utilisation

Behavioural observations revealed considerable variation in ecological roles among ant species. Foraging behaviours were the most frequently observed activities and included solitary foraging, trail following, recruitment, and predatory hunting.

Predatory species such as *Leptogenys*, *Harpegnathos*, and *Anochetus* were primarily associated with hunting behaviour. The processional movement of *Leptogenys processionalis* and swarm raiding by *Aenictus cf. fergusonii* represent highly coordinated foraging strategies that likely improve prey detection and capture efficiency. Such collective hunting strategies enable colonies to exploit prey resources that may be unavailable to solitary predators.

Honeydew collection behaviour observed in *Crematogaster*, *Camponotus*, and *Technomyrmex* highlights the importance of trophobiotic interactions in the study area.

Figure 17. A Camponotus individual tending to aphids on a plant stem

Associations with sap-feeding insects provide a reliable source of carbohydrate-rich food and may contribute significantly to colony growth and persistence.

Seed collection behaviour observed in *Trichomyrmex* and *Pheidole* indicates that these genera may contribute to seed movement and redistribution within habitats. However, the present observations do not demonstrate effective seed dispersal, seed survival, or subsequent effects on plant recruitment. Further studies tracking seed fate and germination outcomes would be required to evaluate the ecological significance of these interactions and their potential role in seed dispersal processes.

Figure 18. Meranoplus bicolor ants scavenging on a Scorpion claw

Similarly, scavenging behaviour recorded in several taxa likely contributes to decomposition processes and nutrient cycling by facilitating the breakdown and redistribution of organic material.

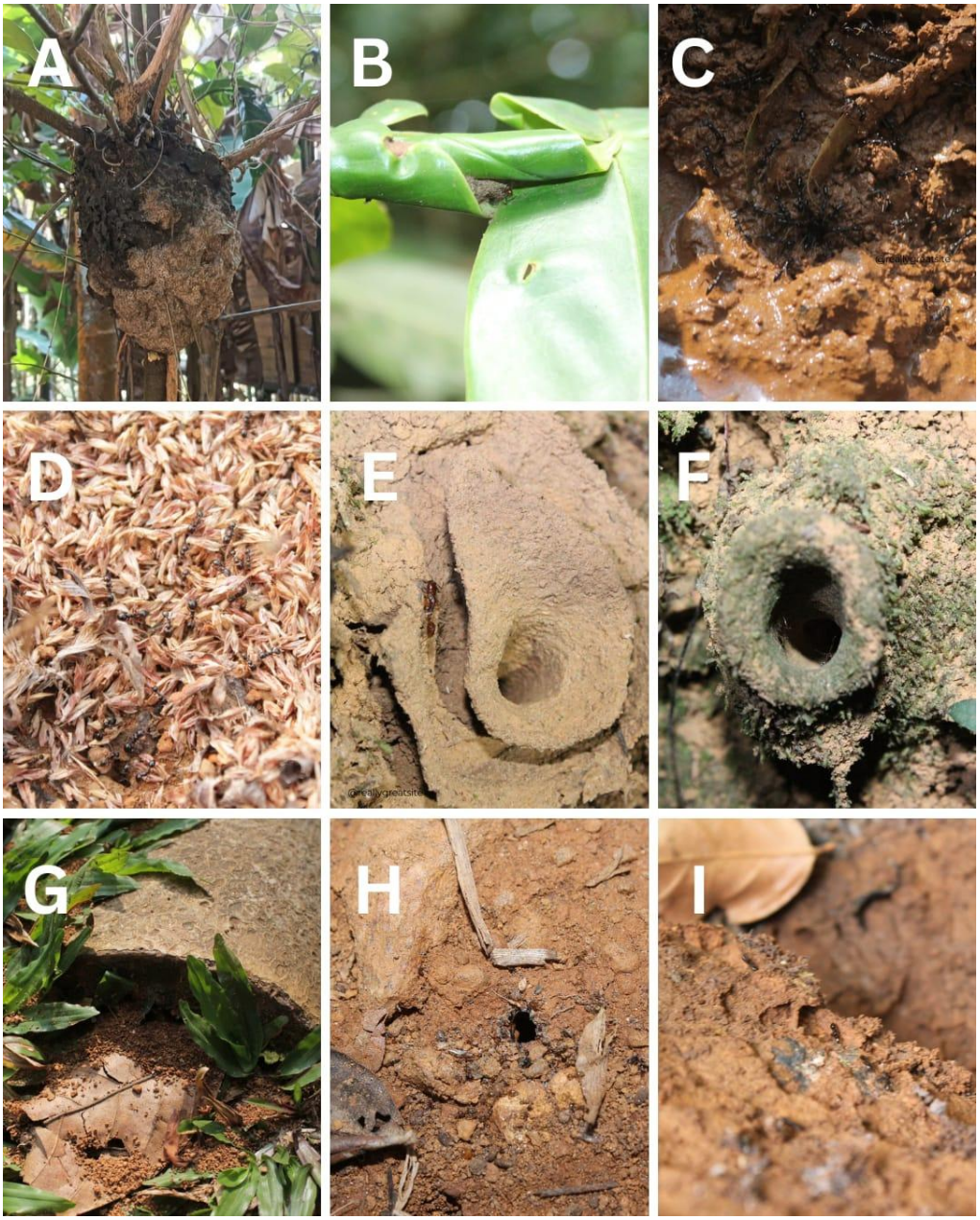


Figure 19. Different types of ant nests recorded in and around Agumbe, Central Western Ghats. (A) Arboreal carton nest of *Crematogaster* built on vegetation. (B) Leaf-fold nest of *Polyrhachis* constructed using rolled leaves. (C) Ground nest of *Leptogenys* in moist soil. (D) *Trichomyrmex* nest surrounded by collected husks and plant debris. (E) Nest entrance of *Anochetus* on a soil bank, with a raised tubular structure that may help prevent rainwater from entering the nest during heavy rainfall. (F) Ground nest of *Pheidole* on exposed soil. (G) Nest of *Brachyponera* located beneath the edge of a fallen areca log. (H) Nest of *Chronoxenus*

found under an areca log. (I) Abandoned ant colony observed beneath a rock in forest habitat. The variety of nest types reflects the use of different microhabitats by ants in the study area.

Brood transport, nest maintenance, recruitment, and defensive behaviours were observed across multiple genera, demonstrating the diversity of social and colony-level activities performed by ants. Differences in foraging strategies, recruitment mechanisms, and resource preferences among species may reduce interspecific competition by allowing taxa to exploit different ecological niches. Such behavioural differentiation has long been considered an important mechanism promoting coexistence within species-rich ant communities.

The wide range of behaviours recorded during the study indicates substantial behavioural diversity within the ant community. This behavioural variation likely contributes to species coexistence and may represent an important mechanism underlying the high levels of ant diversity observed within the Agumbe landscape.

Objective 2: Resource Selection in *Trichomyrmex*

The results demonstrate that *Trichomyrmex* colonies exhibit selective foraging behaviour and do not exploit all available food resources equally.

Figure 20. A Trichomyrmex ant carrying away a grain of sugar during the experiment.

Sugar was consumed most frequently, indicating a strong preference for carbohydrate-rich resources that can provide a rapid source of energy for worker activity, trail maintenance, and colony functioning.

Rice showed intermediate consumption, whereas seeds were consumed least. The significant differences among all resource pairs suggest that colonies were able to discriminate between available food types and consistently selected certain resources over others. The observed preference hierarchy of Sugar > Rice > Seeds indicates that resource selection was non-random and reflects active foraging decisions rather than random encounter rates. A linear mixed-effects model further supported this pattern by showing that resource type significantly influenced food consumption even after accounting for differences among colonies. This indicates that the observed preference was consistent across colonies and was not driven by the behaviour of only a few colonies.

Preference for sugar-rich resources is consistent with the nutritional ecology of many ant species. Carbohydrates obtained from nectar, honeydew, extrafloral nectaries, and other sugar-rich resources constitute an important energy source for worker ants and are frequently

targeted during foraging (Blüthgen & Fiedler, 2004; Kay, 2004). Numerous studies have shown that ants often preferentially exploit carbohydrate-rich resources when available, particularly because these resources support worker activity, recruitment, and colony maintenance (Blüthgen & Fiedler, 2004; Detrain & Prieur, 2014). The strong preference for sugar observed in the present study is therefore consistent with broader patterns reported in ant foraging ecology.

The resources also differed in texture, with sugar representing the roughest resource, rice an intermediate rough-smooth texture, and seeds the smoothest resource. Consequently, it is not possible to separate the effects of nutritional quality and texture in the present experiment. The greater consumption of sugar and rice compared with seeds may indicate that texture influenced handling efficiency, transport, or resource detection by workers. For example, rougher particles may provide improved grip during transport, whereas smoother seeds may require greater handling effort. However, because resource type, nutritional value, and texture varied simultaneously, these interpretations remain tentative. The observed preference may reflect differences in nutritional quality, texture, or a combination of both factors. Experimental studies that independently manipulate resource texture and nutritional content would be required to distinguish their relative importance in shaping resource selection.

The boxplot revealed a consistent preference pattern across colonies. Sugar showed the highest median consumption, rice showed intermediate consumption, and seeds showed the lowest median consumption. Although some overlap occurred among resource types, particularly between sugar and rice, the overall distributions supported the statistical results.

The skewness and kurtosis values further suggest that the observed pattern was not driven by a few unusual colonies. Overall skewness was low (−0.38), indicating that consumption values were approximately symmetrical around the mean. Likewise, kurtosis values were

below 3 for all resource types, indicating relatively light-tailed distributions and a lack of extreme outliers. This suggests that the preference hierarchy was broadly consistent across colonies rather than being influenced by a small number of exceptionally high or low observations.

Overall, the experiment indicates stronger consumption of sugar-rich resources by *Trichomyrmex* colonies under the experimental conditions when multiple resource types were offered simultaneously. The results suggest that resource characteristics, including nutritional quality and potentially physical properties such as texture, may influence resource use by foraging ants. However, because resource type, nutritional content, and texture were not manipulated independently, the relative contribution of these factors could not be determined. These findings provide insight into resource use patterns in *Trichomyrmex* and highlight the need for further studies that experimentally separate the effects of resource quality and physical characteristics on ant foraging behaviour.

12.1 Study Limitations and Future Directions

While the present study provides valuable insights into ant diversity, behaviour, and resource selection in the Agumbe landscape, several practical limitations were encountered during fieldwork.

The study was conducted between December 2025 and March 2026 and therefore represents a relatively short sampling period within a highly seasonal tropical ecosystem. Ant activity, species detectability, resource availability, and community composition may vary across seasons in response to changes in rainfall, temperature, and vegetation phenology. Consequently, the patterns documented here should be interpreted as representative of the study period and sampling conditions rather than the full annual dynamics of ant communities in the region. Longer-term studies incorporating seasonal replication would

provide a more comprehensive understanding of temporal variation in ant diversity and behaviour.

One limitation involved the behavioural observations and resource selection experiments. Individual ants were initially intended to be marked using paint to enable repeated observations of the same workers. However, pilot trials indicated that paint marks added noticeable weight to the ants and appeared to alter their natural movement and behaviour. To avoid introducing behavioural bias, individual marking was not used. Consequently, behavioural observations were conducted at the colony level rather than the individual level. Furthermore, behavioural observations were recorded opportunistically during surveys rather than through a standardized behavioural sampling protocol. As a result, behavioural records are best interpreted as descriptive natural history observations and should not be used to compare behavioural frequencies or activity rates among habitats.

Several challenges were also encountered while attempting to record behavioural data using video. A triangular experimental arena was initially designed to facilitate observation of resource selection behaviour. However, ants frequently climbed out of the arena, making observations difficult. To address this issue, a transparent film was placed over the arena to prevent escape. Although this successfully contained the ants, sunlight reflecting from the film created substantial glare, reducing video quality and limiting behavioural observations. In addition, obtaining high-quality macro videos in the field proved difficult because the available tripod could not be positioned sufficiently close to the arena. As a result, continuous video recording was not feasible, and behavioural observations were instead recorded manually in the field using structured ODK data sheets. While this approach allowed the collection of detailed behavioural information, video-based analyses of individual movement patterns and interactions were not possible.

The resource selection experiment was also influenced by seasonal and logistical constraints. The original intention was to test whether resource structure alone influenced ant choice by using naturally occurring seeds of similar nutritional value that differed in surface characteristics. However, fieldwork was conducted during a period when many local plant species were not fruiting, and sufficient quantities of the same native seed types could not be obtained throughout the study period. To maintain consistency across experimental trials, equal masses of sugar, rice, and commercially available seeds were used instead.

The strong consumption of sugar observed in the experiment may have been influenced by its nutritional value in addition to its physical texture. Previous studies have shown that carbohydrates are an important energy source for ants and can strongly influence foraging decisions (Blüthgen & Fiedler, 2004; Detrain & Prieur, 2014). Because resource type, nutritional content, and texture varied simultaneously, the independent effects of these factors could not be separated. Due to limitations in time, funding, and laboratory facilities, it was not possible to conduct nutritional analyses of the resources used in the experiment. Future studies using resources with comparable nutritional composition but differing textures, or experimentally manipulating texture independently of nutritional quality, would provide a more rigorous test of the role of resource structure in ant foraging decisions.

Ant sampling methods were also affected by the physical characteristics of the study area. Pitfall trapping was initially planned as a major component of the sampling design. However, the rocky terrain, uneven ground surface, exposed roots, and steep slopes made the installation of pitfall traps difficult in many locations. Consequently, visual encounter surveys and active hand collection became the primary sampling methods.

Although pitfall traps are widely used for sampling ground-dwelling ants, different methods often detect different components of the ant community. Romero and Jaffé (1989) found that

the most complete representation of ant diversity was obtained through a combination of hand collecting and pitfall trapping rather than either method alone. Similarly, active searches allow targeted sampling of microhabitats such as leaf litter, fallen logs, vegetation, and nesting sites that may be underrepresented in pitfall samples. The extensive use of visual encounter surveys and hand collection in the present study therefore likely contributed to the detection of a broader range of species across different microhabitats. Abundance estimates were derived from a combination of pitfall trapping, hand collection, and visual encounter surveys. Because these methods differ in their detection efficiency across species and microhabitats, abundance values should be interpreted as relative measures of occurrence and activity rather than absolute estimates of population size.

However, species that are primarily subterranean, cryptic, or restricted to deep leaf litter may have been less effectively sampled than would have been possible with more extensive pitfall trapping, Winkler extraction, or soil-sampling techniques. Future studies incorporating multiple complementary sampling methods may provide a more complete representation of the ant fauna present within the landscape.

Despite these limitations, the study documented a diverse ant assemblage, produced extensive behavioural observations, identified several putatively undescribed species, and generated one of the most comprehensive recent inventories of ants from the Agumbe landscape. Future studies incorporating longer sampling periods, additional trapping methods, automated behavioural recording systems, seasonal replication, and experimental manipulation of resource traits may provide an even more complete understanding of ant diversity and ecology in the region.

13 Conclusion

Overall, the findings of this study highlight the ecological and taxonomic importance of the Agumbe landscape. A total of 75 ant species were documented across forests, areca plantations, and grasslands, demonstrating the high diversity of ant communities within the region. Forest habitats supported the highest richness, abundance, and diversity, emphasizing the importance of structurally complex habitats in maintaining diverse ant assemblages. Behavioural observations revealed a wide range of ecological roles, including predation, scavenging, honeydew collection, seed collection, brood transport, recruitment, and nest maintenance, suggesting that differences in resource use and foraging strategies may facilitate species coexistence within the community.

The study also yielded several important taxonomic findings, including ten potentially undescribed species, new state records of *Strumigenys mutica* and a *Paraparatrechina* morphospecies, and observations of worker polymorphism in *Lepisiota wroughtonii*. These findings indicate that substantial undocumented ant diversity remains within the Western Ghats despite ongoing research efforts. The resource selection experiment further demonstrated that *Trichomyrmex* colonies exhibit clear preferences among food resources, suggesting that both nutritional quality and physical characteristics influence foraging decisions.

Together, these results provide a valuable baseline for understanding ant diversity and ecology in the central Western Ghats. Future studies incorporating longer-term monitoring, seasonal sampling, additional collection methods such as Winkler extraction and canopy surveys, and integrative taxonomic approaches combining morphology and molecular data may further improve our understanding of ant biodiversity, community organisation, and ecosystem functioning in the region.

The findings of this study also have important conservation and management implications. Forest patches supported the highest ant diversity and contained the greatest number of habitat-associated species, highlighting their importance as biodiversity reservoirs within the landscape. Maintaining forest remnants, preserving leaf litter and other microhabitats, and promoting wildlife-friendly management practices in areca plantations may help conserve ant diversity and the ecological functions they perform. The identification of habitat-specific indicator species further suggests that ants could serve as useful bioindicators for monitoring habitat quality and ecological change in the region.

14 Appendix

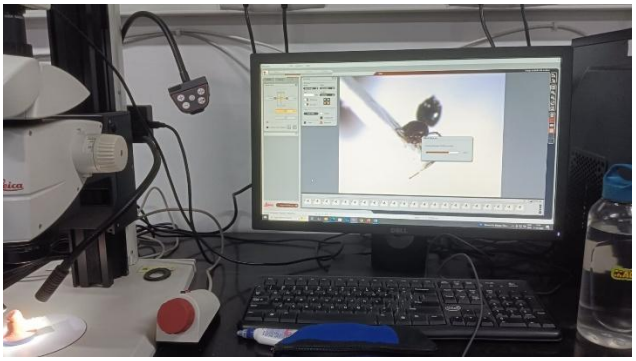
Sharing some photographs from field:

Photographing ants on field using macrolens.

Searching for ant queens on UV Light traps.

Pinning and Point mounting collected specimens of ants in the field.

Multiple Outreach sessions were conducted with local and international educational institutions.



Photographing putatively undescribed ant specimens using a Stereo Microscope at NCBS Collections facility

A planthopper nymph spotted in Agumbe. The waxy filament like 'tail' acts as a decoy, tricking predators into attacking the tail, while the nymph hops away.

Kalanchoe pinnata is a succulent whose flowers are commonly known as Cathedral Bells, due to their bell-shaped blooms. They were flowering during the study period.

Common Mapwing Butterfly. Lepidopteran diversity was very high in the study area.

Sri Lanka Bay Owl (*Phodilus assimilis*) with a rodent kill in its mouth. Nocturnal fauna activity was also high.

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