ANTS HABITAT MAPPING USING REMOTE SENSING AND GIS

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Abstract

Ants' form one of the very dominant arthropods with more than 10,000 described species. Their presence, more often their dominance in extremes of climates and a variety of habitats is overwhelming. Ants reveal the status of the ecosystems and are considered as good biological indicators. This necessitates spatial distribution analyses along with mapping of its habitats. This helps to understand ant geography and also to determine the kind of the stress levied on the ecosystem. This research is being carried out in the Sharavathi river basin (13°43′24.96 N to 14°11′57.48 N latitude and 74°40′58.44 E to 75°18′34.92 E longitude) in the central Western Ghats of Karnataka state, India.

Multi spectral data with 23.5 m spatial resolution acquired from Indian Remote Sensing (IRS) Satellite was used to determine the land cover and land use in the study area. The application of vegetation indices to delineate vegetative and non-vegetative areas determined 70% of the study area under vegetation cover. False color composite was generated with IRS (Indian remote Sensing) data (0.52 – 0.59μ m, 0.62 – 0.68μm and 0.77 – 0.86μm), which helped in the selection of training polygons. A numerical description of the spectral attributes of each land use type was developed (supervised classification) using Maximum Likelihood Classifier. This also helped in identifying 14 landscape elements (LSE's). To analyze the spatial distribution of ants, a converging sampling strategy was adopted in four radial directions. Along each direction at every four km, three samples were laid at a 200 m distance, resulting in a total of seventy-eight 30 x 30 m quadrants, each of those were marked using a GPS (Global Positioning System). Sampling was carried out in representative LSE's (seven LSE's) in varying replicates to determine the ant fauna by using pitfall traps, leaf litter collections, bait traps, and visual collections. The ants were then identified and the pooled data of various sampling techniques (pitfall traps, leaf litter, etc.) were quantified to compute Land Scape Element wise species richness and composition. Data analysis results

reveal that ant species richness increased where a mosaic of habitats (more diverse habitats) were present. Moist deciduous forests are the most ant rich habitats and evergreen forests have the highest ant species per plot richness. Species such as *Anoplolepis longipes* are present in habitats (except evergreen and semi-evergreen forests) that are closer to human settlements indicating human interference with the ecosystems, while, species such as *Harpegnathos saltator* is present only in undisturbed systems. *Polyrhachis mayri* was found only in highly undisturbed semi evergreen forests. Forest patches with small breaks in canopy covers provide the specific niches required for *Pachycondyla rufipes*. Arboreal ants as *Oceophylla smaragdina* and *Polyrhachis* species are present in heterogeneous forest patches but are totally absent in monocultures (like plantations, etc.). However, the niches in Acacia plantations (72% of the sampled Acacia plantations) harbour the specialist predator *Diacamma rugosm*. Scrub jungles are deprived of all species of *Leptogenys*. This reveals the intra and inter linkages of landscape elements with species distribution, which is essential for conservation of endemic, rare and endangered species of flora and fauna. This endeavor demonstrates the application of the spatial analyses tools such as GIS, GPS and remote sensing data in habitat mapping and spatial distribution analyses of biodiversity. These exercises help in evolving the appropriate conservation and restoration strategies for the sustainable management of ecosystem.

INTRODUCTION

Remote sensing techniques help in acquiring spatial data at various time intervals (temporal data) of earth resources, which aid in inventorying, mapping and sustainable management of resources. It offers a quick and efficient approach to analyse the drivers responsible for land use changes, which has implications on flora and fauna distribution. The multi spectral temporal data are being used effectively for quantification and monitoring of natural resources. This helps in demarcating areas of deforestation, changes in crop productivity, location of groundwater, mineral, oil and other metals, which are required for managing the resources. Remote sensing data and GIS have immense value in mapping of resources and assessment of energy demand on spatial scale. Major application includes,

- Land cover analysis
- Land use classification and evaluation of land resources
- Monitoring and management of natural resources

The terms land use and land cover are often used in natural resources management, meaning types or classes of geographical determinable areas. Land cover analysis is done to discern vegetation, hydrological or anthropogenic features on the land surface. Land cover provides the ground cover information for baseline thematic maps. The land cover features can be classified using the data of different spatial, spectral and temporal resolutions. Broadly speaking, land cover describes the physical state of the Earth's surface and immediate surface in terms of the natural environment (such as vegetation, soils, groundwater, etc.) and the man-made structures (e.g. buildings). In contrast, land use refers to the various applications and the context of its use. This involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation (the purpose for which the land has been used). Land use and Land-cover information play an important role at local and regional as well as at macro level planning. The land-cover changes occur naturally in a progressive and gradual way, however sometimes it may be rapid and abrupt due to anthropogenic activities. The planning and management task is often hampered due to insufficient information on the rates of land-cover and land-use change. Identifying, delineating and mapping land cover on temporal scale provides an opportunity to monitor the changes, required for sustainable management of natural resources. Thus, GIS and Remote Sensing allow spatial analysis approach to address the issues related to conservation and sustainable management of ecosystems

Remote sensing in the field of conservation and management of natural resources has varied applications. Aerial photography has been used for census of wildlife especially marine mammals, and carnivores in savannas. It is also used in monitoring the movement of wildlife. But the increasing applications of remote sensing have been primarily in the area of plant sciences. Practically most of the work done in remote sensing revolves around vegetation classification, crop monitoring and harvesting, mapping patterns in different forests, range lands, agricultural lands and diseases detection in crops (James, 1996). GIS along with remote sensing data help in inventorying, monitoring and assessing the natural resources on both spatial and temporal scale.

Increasing interest is being expressed worldwide in conservation largely as a result of a serious concern that has dawned due to the present state of local and global environmental conditions. This awareness is based on the recent realization that the state of the biological systems is of fundamental importance for the survival of human community. A key part of the global conservation effort is the mapping of biodiversity to pinpoint the hotspots, the most threatened and also the most species rich ecosystems of the world. With the increasing availability of global remote sensing data sets of high resolution it is important to combine field surveys to provide more accurate resource assessments. It being impractical and impossible to determine all the species or sample at all the places in a particular ecosystem, knowledge of presence and absence of certain indicator species has been favored in assessing the degree of stress and disturbance on the ecosystem. The most often used indicator species as trees, birds, butterflies and higher mammals are easy to sample and monitor and also represent diverse groups of biological significance. But not all exhibit interrelations with diversity of other taxa nor show response to changes in the ecosystem (Oliver and Beattie 1996).

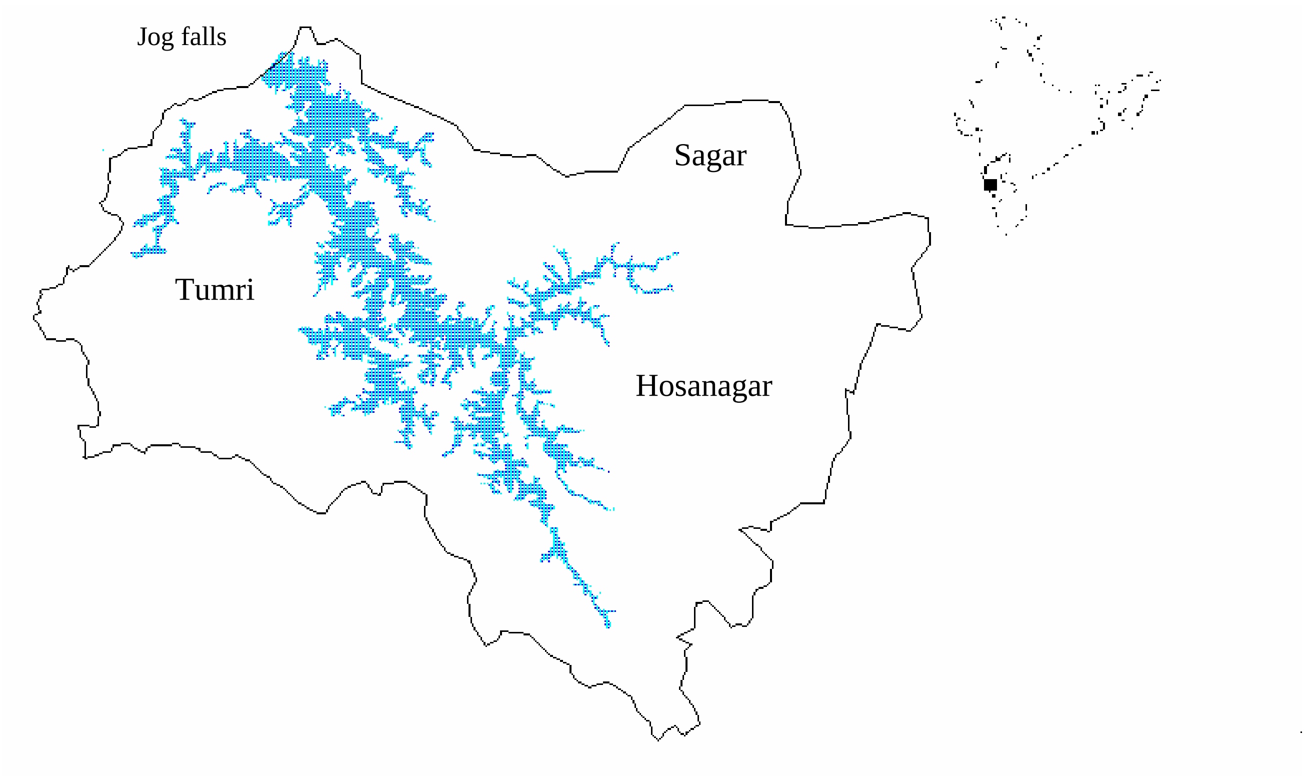
Ants due to their high diversity (about 9600 species worldwide), high abundance, intricate relations and mutualistic behavior with both flora and fauna qualify as excellent ecological indicators (Agosti *et al* 2000). Ants belonging to the family *Formicidae,* super family *Vespoidea,* order *Hymenoptera*, are relatively less known in the Indian scenario wherein 600 species of ants have been identified (Bingham, 1975; Veeresh and Ali, 1987). Ants constitute 15% of the total animal biomass in a Central Amazonian rainforest (Fittkau and Klinge, 1973). Studies carried out by Erwin (1989) at Peru showed that 69% of the total insect specimens collected by fogging the forest canopy were ants. Wilson (1987) has reported that a single tree in Peruvian tropical lowland forest yielded 26 genera and 43 species of ants. Sampling in 33 one-hectare plots from 12 habitats at the Western Ghats, Gadagkar *et al* (1990) have reported 120 species from 31 genera in Uttara Kannada district. Ants tend to be very aggressive and have great ability to dominate themselves because of which direct interactions between them and plants and also with other arthropods and insects are distinctly seen. Ants exhibit high degree of variability in food preference. Some cultivate fungus gardens to meet their food requirements, some are accomplished scavengers and necrophagous while a majority of species serve as general predators on other insect groups exerting enormous pressure on other invertebrate populations in their habitats. Members belonging to the primitive genera of *Amblyopone* sustain mainly on centipedes (Dumpert, 1978), *Leptogenys processionalis* and *L.chinensis* on termites (Shivshankar, 1985) while *Strumigenys, Cerapachys, Proceratium* are specialized predators that feed on restricted set of arthropods (Kaspari, 2000). *Eciton burcelli* consumes more than 10000 captured animals per day, a majority of which are insects (Dumpert, 1978). Some ants survive on plant exudates (Tennant and Porter 1991). The diversity seen in ant fauna globally suggests that their ability to survive in various biotopes, is due to their specialized nesting structures to suit different environmental conditions. Ant nests vary from small crevices in buildings to anthills over 1m in height and 9m in circumference. Ants also nest under stones, in plants (myrmecophytes) and makes carton nests on trees. Together with *Homo sapiens,* ants are one of the few animal groups that commonly manipulate and modify their surroundings to suit their needs and it's a truism that they occupy a position among terrestrial invertebrates equivalent to that occupied by our species in/among the vertebrates (Bolton 1995). They offer insight to ecosystem functioning to those who are interested in long-term monitoring, inventory and ecology.

Most of the ants have either a direct or an indirect relationship with vegetation. Some of these are highly specific to the habitat in which they occur, depending on the maximum benefits they attain for nesting, mating and food availability. Their preferences of microhabitat due to the above mentioned criteria were investigated by sampling ant fauna in various habitats along with mapping the vegetation using remote sensing and GIS (macro level analyses) to provide a detailed idea of the distribution of ant fauna, endemism and changes in patterns with habitat. By further determination of spatial distribution of certain indicator ant species the degree of stress and disturbance for prioritizing conservation strategies for this section of the Western Ghats was analyzed.

STUDY AREA

The Linganamakki catchment of the Sharavathi river basin is located between 13°43′24 N and 14°11′57 N, 74°40′58 E and 75°18′34 E in the central Western Ghats (Fig 1), with an elevation ranging between 80 and 1340 m. It spans Hosanagar, Sagar, and Thirthahalli taluks covering a total area of 2000 sq kms. Maximum rainfall occurs during the monsoon between June and September. (data collected from Drought Monitoring Cell, Bangalore).

Figure 1. Location of Study area



Large patches of undisturbed evergreen forests are present towards the western region of the study area (**Fig 1**) at Nagodi, Karni and Kodachadri wherein indicators of climax vegetation as *Poeciloneuron indicum, Myristica dactyloides* along with *Dipterocarpus indicus, Aglaia anamallayana, Holigarna grahamii* and *Ficus nervosa* are present. Poor regeneration of the deciduous species as *Terminalia paniculata*, *Terminalia tomentosa*, *Terminalia bellarica, Lagerstroemia microcarpa,* ascertained the presence of fire in the past. The shrub layer is dominated by *Psychotria flavida, Pinanga dicksoni, Polyalthia fragrance, Strobilanthus* species. A scrub savannah habitat with barren hilltops characterizes the 25km stretch from the reservoir on the western region to Tumri. Along the southeastern region, evergreen forests are found as small fragments along with deciduous species, covering Sharavathi state forest, Hilkunji, Nilvase and Kavaledurga. The extreme levels of encroachment and land utilization for various anthropogenic purposes were seen in the planes towards the eastern region. This suggests the uneven jagged topography in the southeast to have been the savior of these forests. Large areas of state forests towards the northeast have been converted to monoculture plantations of Acacia. The eastern region also had an unprecedented increase in the agricultural and wasteland area, built-up regions and tree savannahs. In the northeastern region the invasive weed *Euphatorium odoratum* dominated, indicating extreme degree of disturbance.

Anthropogenic activities in recent times has resulted in large scale fragmentation, creating a mosaic of land cover patterns of agricultural fields, monocultures of acacia, eucalyptus, rubber, arecanut, pine, casuarina and cashew along with evergreen forests, moist deciduous and scrub jungles in the river basin.

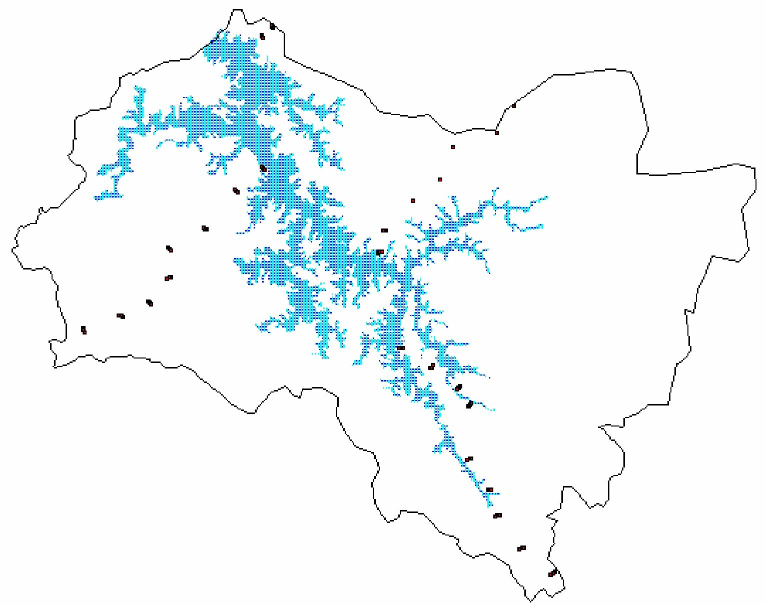
MATERIALS AND METHODS

Land cover analysis was done to delineate the areas under vegetation and soil (non-vegetation). The land use analysis was carried out for the region to identify the use of land, emphasizing the functional role of the land in economic activities. Land use patterns reflects the characters of a society's interaction with the physical environment, while land cover in its narrowest sense often designates only the vegetation cover extent on the Earth's surface, as the spectral reflectance in green band (visible range of em spectrum) and near-infrared would represent the photosynthetically active vegetation. A cloud free IRS-1C satellite multi spectral imagery of LISS III sensors with spatial resolution of 23.5m was used for the analyses. Land cover analyses were done through computation of vegetation indices which could be Slope based or distance based (depending on the landscape type - hilly, arid, etc.). The Normalized Difference Vegetation Index (NDVI) was used to delineate vegetative from the non-vegetative features. High values in a vegetation index identify pixels covered by substantial proportions of healthy vegetation. Due to inverse relationship between vegetation brightness in the red (R) and near infrared (IR) region, a normalized difference ratioing strategy can be very effective. Once the extent of vegetation cover was determined, further analyses were done to classify image with field data. FCC image was generated by merging all 3 bands, which aided in identifying the heterogeneous patches for selection of training sites. Attribute information corresponding to these training sites were collected from field using Global Positioning System (GPS). In addition to this, GPS was used to map the tree species, which were sampled along 200 m transect with 20 x 20m quadrant. Gaussian maximum likelihood classifier was used to classify the data based on the attribute data collected from field. The statistical probability of a given pixel present in a specific land use category was calculated and each pixel in the data was categorized into the land use class it most closely resembled or the probability of occurrence.

SAMPLING STRATEGY FOR ANTS:

Sampling was done along four transects (**Fig.2**) moving away from the reservoir towards the end of the river basin. The undulating topography in the area resulted in non-uniform length of the transects that varied from 4 km to 32 km. Three sampling plots, 30 sq. m each, were located at every 4 km distance along the transects. These plots were placed in a mini-transect of 400 m at a 200 m interval, perpendicular to the main transect resulting in a total of 78 plots, distributed across moist deciduous forests, semievergreen, scrub jungles, acacia plantations, semievergreen forests, evergreen forests and pine plantations. At each of these plots the entire package of baits (described below) were laid for collecting ants. The catchment area being very small in the northern region (being very close to the dam), resulted in six (2x3) samples.

Fig 2: Sampling location for ants (Each sampling plot [30x30 sq m] is represented by a dot)

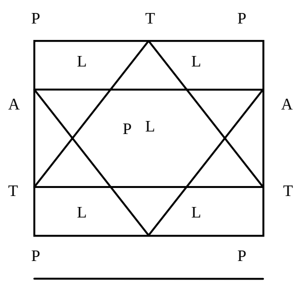


SAMPLING METHODS:

Ants live in different strata of the ecosystem as their nests vary from thick leaf litter, dead wood, modified nesting structures provided by plants, tree canopies and soil. In view of this ants cannot be collected by one technique and hence different methodologies of collection were employed. Ants were collected from each plot using bait traps, pitfall traps, leaf litter techniques and visual collections.

Terrestrial and arboreal baits were placed using 70% honey, tuna fish and fried coconut. Terrestrial baits (T) were placed on the ground (**Fig 3**) and the arboreal baits were tied to a tree at a height of 6 ft from the ground. A 10cm long cylindrical tube containing 90% ethyl alcohol with 3 drops of glycerin was used for a pitfall trap (P). A pit was dug with a mallet and the tubes were placed such that their mouth was flush with the ground. Five such pitfall traps were laid at every sample for a 24h period. The Burlese leaf litter technique was used in extracting ants from the leaf litter in four, 1x1m quadrants at each sub sample. The quadrants were placed in the four smaller quadrants (L), between the pitfall traps and baits in four directions. A visual collection was done for a period of an hour, which involved sweep net method, checking in barks, rotting logs and on leaves. From all traps insects were sorted and ants were separated for identification and preserved in 70% ethyl alcohol.

Fig 3: Sampling layout



ANALYSES: As ant colonies show spatial clumping, counting the number of individuals of each captured species would be inappropriate. Hence the frequency of occurrence of each species in each habitat was determined and is termed as abundance. The Shannon's diversity index is computed to determine ant diversity in habitats, which is a measure of the average degree of *uncertainty* in predicting to what species an individual chosen at random from a collection of *S* species and *N* individuals belongs. This diversity increases as the number of species increases and as the distribution of individuals among the species becomes even. It is given by,

$$H' = -\sum_{i=1}^{S^*} (p_i \ln p_i)$$

where, H' = average uncertainty per species in an infinite community made up of S* species with known proportional abundances $p_1, p_2, p_3, \ldots p_s$; p_i = proportional abundance of i^{th} species (Ludwig and Reynolds, 1998).

Evenness across habitats was computed by the *Pielou's evenness index,* H'/logS, S being the number of species recorded over all the sites, wherein maximum values would be when all species are equally abundant.

Jaccards similarity index was used to analyze extent of similarity between habitats with respect to ant fauna. It is calculated as, O_{ij} = c/a + b – c; where, O_{ij} = overlap between habitats; c = no of species overlapping between i and j; a = no of species in habitat i; b = no of species in habitat j (Pramod, *et al*, 1997).

The maps of the study area were digitized using Mapinfo 5.0 (creation of vector layers). IDRISI was used to determine the NDVI index and also to arrive at a second level classification using a supervised classification approach - Maximum Likelihood Classifier (raster analyses). Geographic Resource Analysis Support System (GRASS) was used to build the 3-D image depicting high and low species richness of ants for the entire study area.

RESULTS AND DISCUSSIONS

Land use - land cover mapping: Computation of NDVI index (**Fig 4**) resulted in identifying 70% of the land to be under vegetation cover. NDVI also revealed dense canopy covers in the western region of the study area, while large agricultural fields were present towards the eastern region. A composite image was (**Fig 5**) analyzed to identify sites for training data collection. A supervised classification of the region resulted in identifying semievergreen to evergreen and moist deciduous forests to be very prominent in the entire study area (**Fig 6**). This region represents a mosaic of forest types with semievergreen to evergreen forests, deciduous forests, agricultural fields, built up regions, scrub lands and wastelands.

Fig 4: Normalized Difference vegetation Index

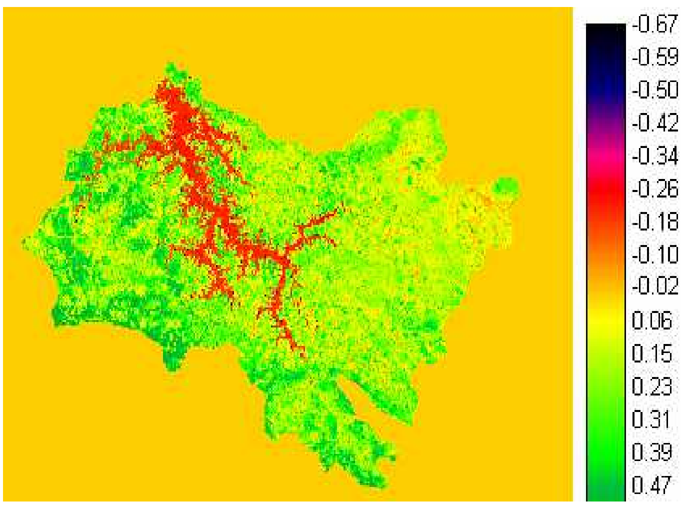


Fig 5: Composite image

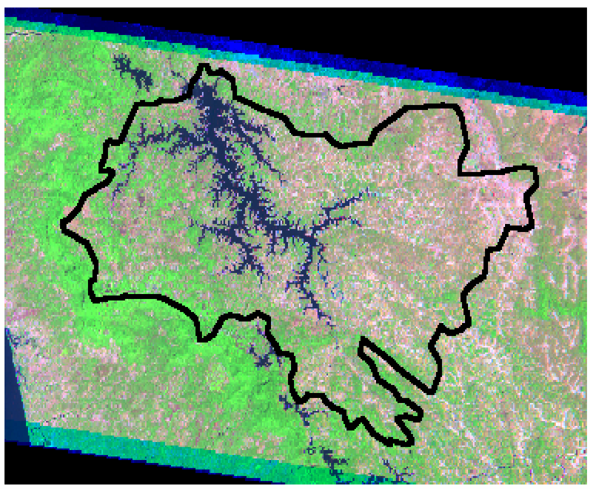
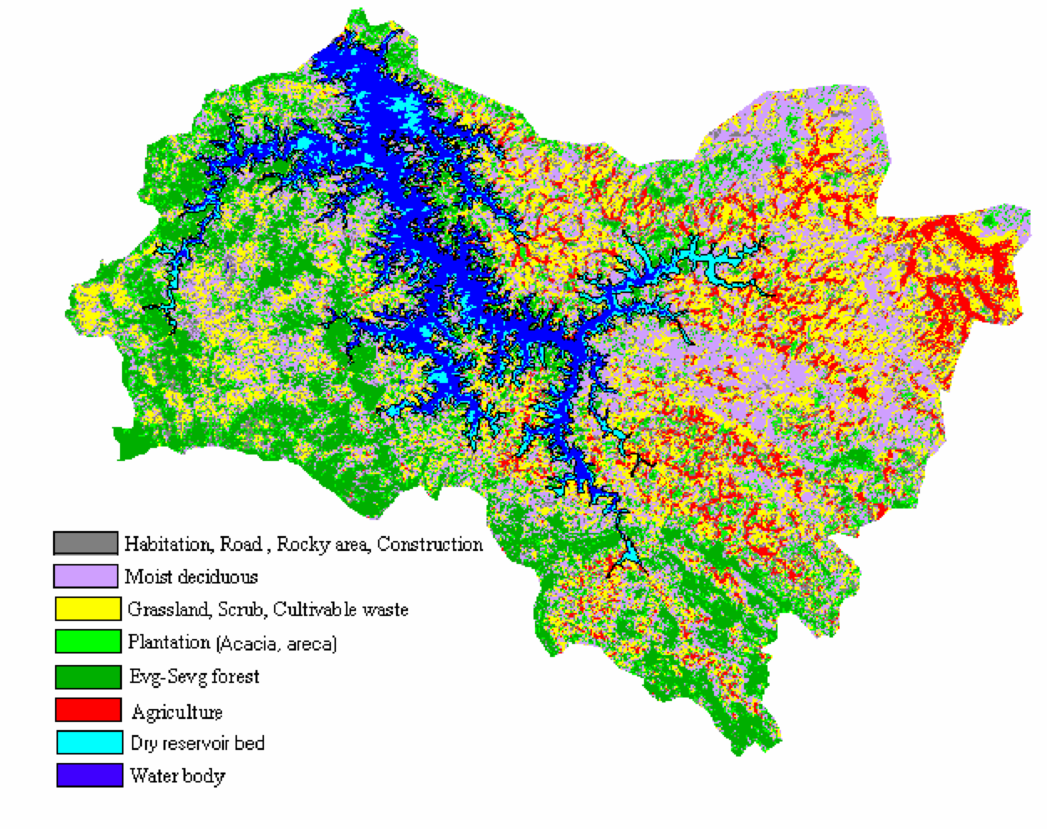


Fig 6: Supervised classification of the Linganamakki catchment of Sharavathi river basin.



Ant diversity: A total of 84 species representing 31 genera and 5 subfamilies were collected from the study area, with an average of 9 (± 3) species per quadrat. Species richness varied from a least of 7% of the total in pine plantations to a maximum of 76% in moist deciduous forests. Sampling revealed moist deciduous forest to harbour the most diverse ant species (**Fig 6**) while evergreen forests had the highest species density. Scrub jungles recorded a higher species density than acacia plantations, despite having a similar species percentage (51%). Ant species were more evenly distributed in evergreen forests (**Fig 7, Fig 8**) than the lesser but uniform evenness exhibited in other habitats. Acacia plantations though had moderate levels of diversity, not many specialized species were present in this habitat. Most of the species belonged to generalized category of ants along with certain known tramp species. Similarity index (**Fig 9**) revealed no overlapping of species between pine plantations and evergreen forests, stressing on the unique compositions each of them harbour due to the change in the vegetation structure and composition. Maximum similarity was seen between moist deciduous and dry deciduous forests while plantations were extremely dissimilar from all the other habitats.

Fig 7:Shannon's index of diversity

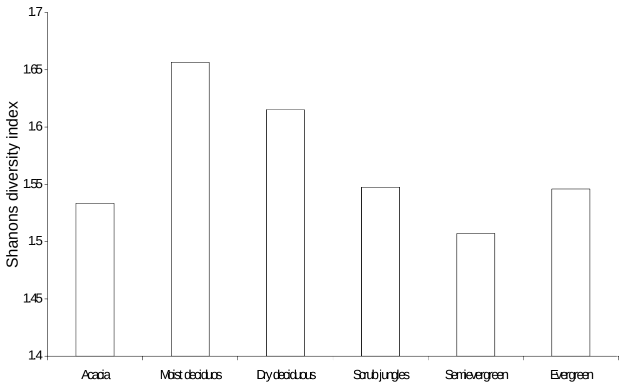
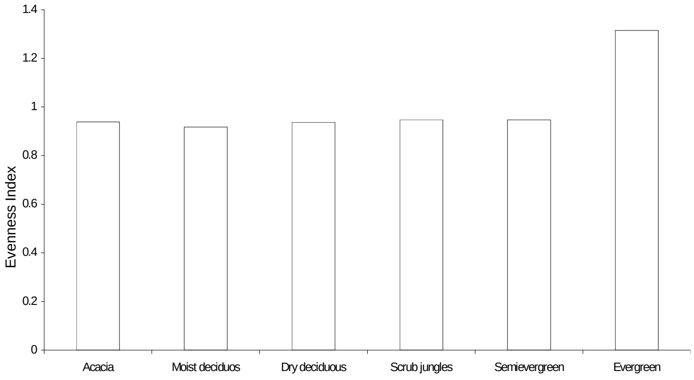


Fig 8: Pielou's Index of Evenness



Spatial distribution and composition: A consistent high ant species richness was seen towards the western region of the study area wherein undisturbed evergreen forests were present (**Fig 10**). Species richness was high in few regions close to the reservoir towards the east wherein small fragments of evergreen forests were present. Species composition in such fragments however varied with more generalists causing the diversity. High diversity was seen even to the southern region, the Kavaledurga state forest, which harbors relatively less disturbed evergreen and moist deciduous forests. The evergreen forests comprised extremely of specialized predators as *Harpegnathos saltator*, *Diacamma rugosm, Pachycondyla rufipes* and cryptic species as *Monomorium dichroum* and *Bothriomyrmex sp*. Scrub jungles had a composition of hot climate specialists (*Meranoplus* and *Lophomyrmex*) ants along with those that were dominant in open canopy areas and during sampling we have been able to delineate certain ant species for their niche specificity to determine the degree of stress and disturbance in the ecosystem.

Fig 9

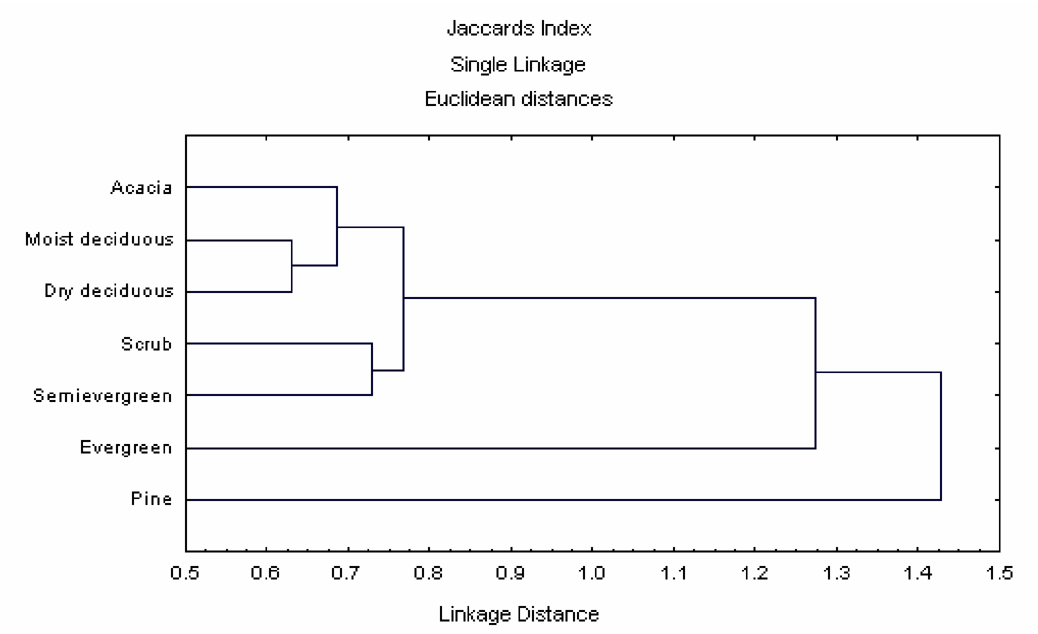
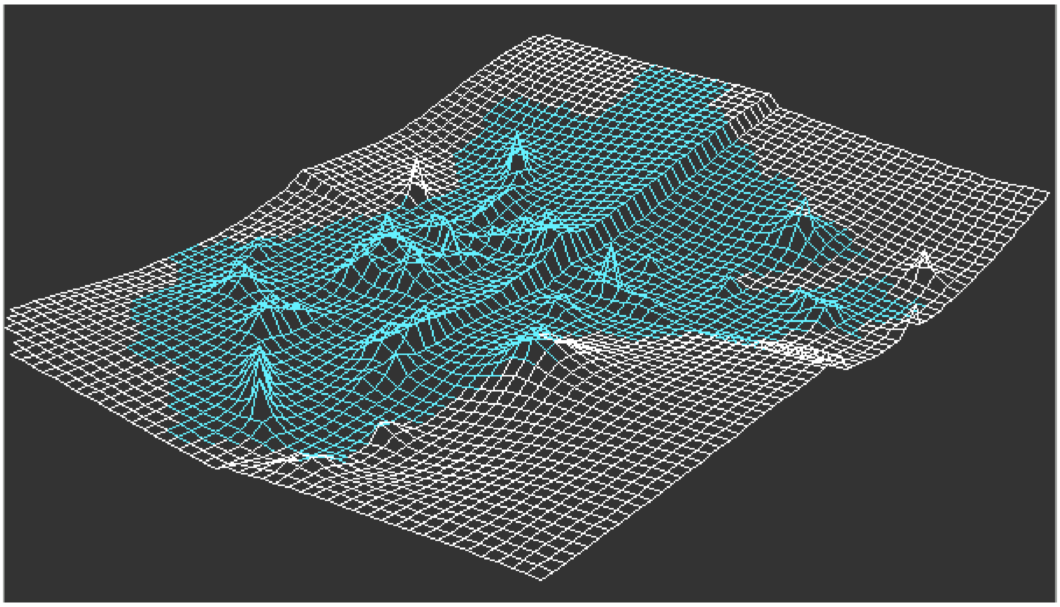


FIG 10: 3-D image of Ants' diversity at the Sharavathi river basin (using GRASS)



Oecophylla smaragdina, the green weaver ant is a truly arboreal species that predominantly nests only in shady areas and trees that have broad leaves, hence being abundant in moist deciduous, semi evergreen and evergreen forests. However they are totally absent from plantations as Acacia sheds (**Table1**) leaves being a deciduous species and also because plantations neither provide the required shady areas nor do they provide broad leaves to make nests. They are abundant towards the western region of the study area and also in some fragments of evergreen forests and moist deciduous forests towards the southern and eastern regions. They are totally absent from the first half of the western transect as a scrub savannah habitat dominates this region (**Fig 11**). Yet another arboreal species of ant *Polyrhachis mayri* is a specialist that nests in the hollows crevices of trees. This species is totally absent from plantations, scrublands and dry deciduous habitats (**Table 1**). It is present only in contiguous undisturbed evergreen forests and moist deciduous forests which are present in the western region only (Karni range forest) (**Fig 12**).

Pachycondyla rufipes, a specialist Ponerine predator is a solitary forager, present in canopy breaks or canopy gaps in the forest. Canopy gaps are created in dense forests due to some kind of anthropogenic pressure, as logging or man made fire. However this species is absent from open canopy areas of the scrublands preferring only gaps in dense forests (**Table 1; Fig 13**).

Table 1: Ant compositions in different habitats are listed (generic level)

Acacia plantations	*Anoplolepis, Aphaenogaster, Camponotus, Cataulacus, Crematogaster, Diacamma, Dolichoderus, Leptogenys, Lophomyrmex, Meranoplus, Monomorium, Pachycondyla, Paratrechina, Pheidole, Pheidolegeton, Technomyrmex, Tetramorium, Tetraponera.*
Pine plantations	*Anoplolepis, Camponotus, Dolichoderus, Platythyrea, Pheidolegeton.*
Moist deciduous	*Acantholepis, Anoplolepis, Aphaenogaster, Camponotus, Cardiocondyla, Cataulacus, Crematogaster, Diacamma, Dolichoderus, Harpegnathos, Leptogenys, Lophomyrmex, Meranoplus, Monomorium, Myrmicaria, Oecophylla, Pachycondyla, Paratrechina, Pheidole, Pheidolegeton, Polyrhachis, Prenolepis, Tapinoma, Technomyrmex, Tetramorium, Tetraponera.*
Dry deciduous	*Acantholepis, Anoplolepis, Aphaenogaster, Camponotus, Cardiocondyla, Cataulacus, Crematogaster, Diacamma, Dolichoderus, Leptogenys, Lophomyrmex, Meranoplus, Monomorium, Myrmicaria, Oecophylla, Pachycondyla, Paratrechina, Pheidole, Pheidolegeton, Polyrhachis, Prenolepis, Recurvidris, Tetramorium, Tetraponera.*
Scrublands	*Anoplolepis, Aphaenogaster, Camponotus, Cardiocondyla, Crematogaster, Diacamma, Dolichoderus, Harpegnathos, Holcomyrmex, Lophomyrmex, Meranoplus, Monomorium, Myrmicaria, Pachycondyla, Paratrechina, Pheidole, Pheidolegeton, Polyrhachis*, *Solenopsis, Technomyrmex, Tetramorium, Tetraponera.*
Semievergreen	*Aphaenogaster, Camponotus, Crematogaster, Diacamma, Harpegnathos, Leptogenys, Meranoplus, Monomorium, Myrmicaria, Oecophylla, Pheidole, Pheidolegeton, Polyrhachis, Prenolepis, Tapinoma, Tetramorium, Tetraponera.*
Evergreen	*Bothriomyrmex, Cardiocondyla, Cataulacus, Crematogaster, Harpegnathos, Leptogenys, Monomorium, Oecophylla, Pheidole, Pheidolegeton, Polyrhachis.*

Anoplolepis longipes, a Formicine is one of the invasive species of the Western Ghats. This species is extremely dominant in areas subjected to human stress and disturbance. This species is extremely abundant in the northern regions, close to the reservoir in the south, (**Fig 14**) and in forests prone to illegal logging and lifting leaf litter. They were well dispersed and distributed in the eastern region contrary to which they were absent from evergreen forests as they were left undisturbed (**Table 1**).

Distribution of ant indicators species through the Sharavathi river Basin

Fig 11 *Oecophylla smaragdina*

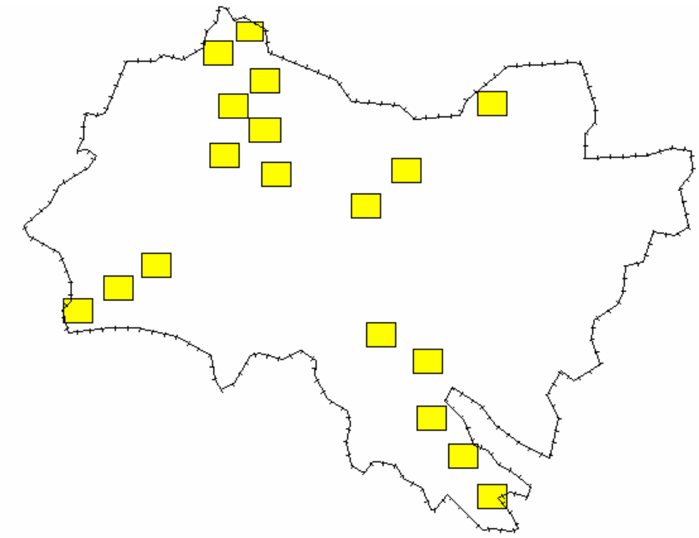


Fig 12 *Polyrhachis mayri*

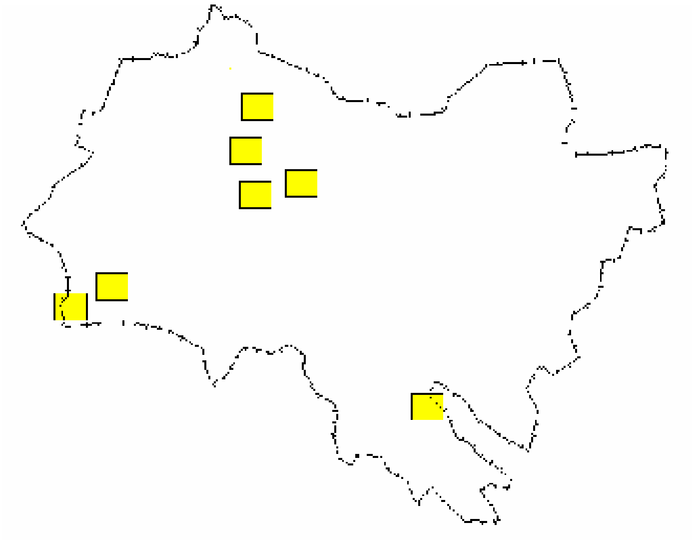


Fig 13 *Pachycondyla rufipes*

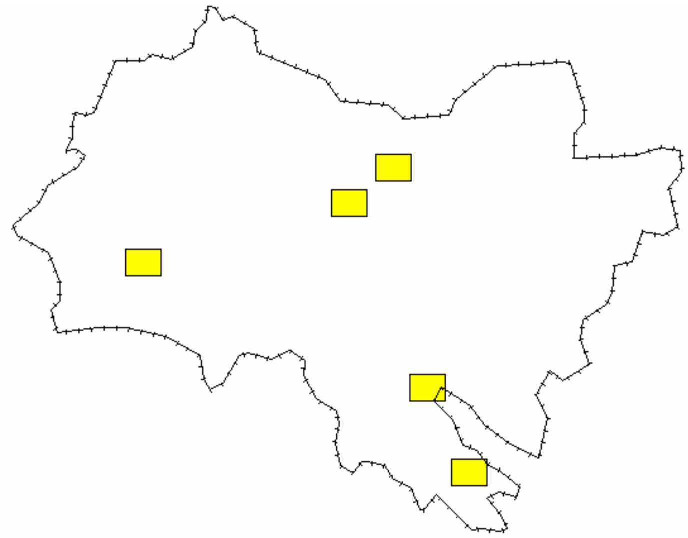
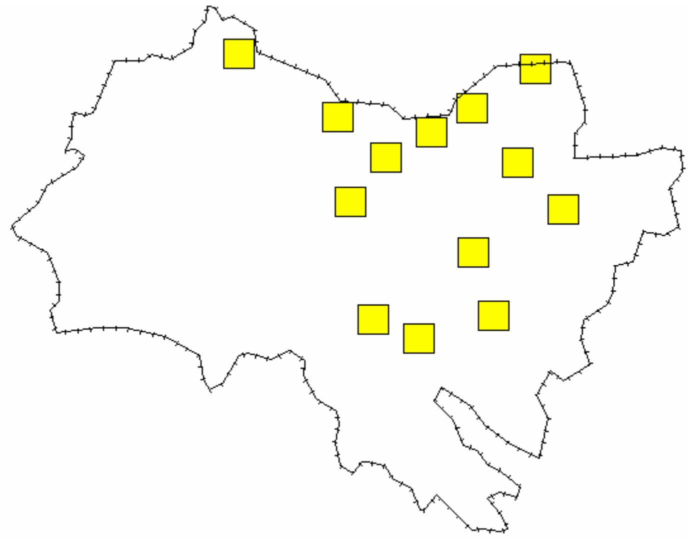


Fig 14 *Anoplolepis longipes*



CONCLUSION

The results revealed that ants could be used as habitat status indicator. The patterns of ant composition in different habitats depended on the dissimilarity between scrublands, plantations, moist deciduous forests and evergreen forests.

Ant species richness along with increasing number of specialized predators were high in the comparatively less disturbed and large contiguous patches of evergreen forests. Absence of invasive ant species in this habitat indicates minimal human interaction

The eastern and northern portion of the Linganamakki catchment , which was subjected to human pressure, has led to differing composition of ants, wherein hot climate specialists were more prominent while arboreal species were totally absent.

The conversion of forests to monoculture plantations shows moderate levels of diversity without many specialized species. This highlights the need to maintain biodiversity.

The northern region of the study area (Bellani state forest) was completely disturbed and forests were cut to pave way to Acacia plantations, has resulted in the absence of arboreal species. Also in such areas a resurgence of generalists had been noted.

The absence of canopy gap specialists in the contiguous forests of the western region (Karni range forest) supported the existence of such undisturbed vegetation patches, which need to be conserved and managed efficiently.

The presence of *Anoplolepis longipes* towards the northern region and southern region (close to the reservoir) are regions which need immediate attention as they are under extensive human pressure. With lack of close canopy in such areas, *Oecophylla smaragdina* is absent while the open canopy and hard soil has resulted in the dominance of *A.longipes*, the invasive species.

Spatial tools such as GIS and remote sensing data helped in habitat mapping and linking fauna diversity and abundance with the status of landscape elements. This helps in formulating habitat conservation and management plans.

An integrated approach of using remote sensing and GIS applications for understanding the habitat requirement of ants in framing management rules for conservation purposes has proven to be well balanced.

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