

Remote detection and distinction of ants using nest-site specific LISS-derived Normalised Difference Vegetation Index

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Abstract. This study in Western Ghats, India, investigates the relation between nesting sites of ants and a single remotely sensed variable: the Normalised Difference Vegetation Index (NDVI). We carried out sampling in 60 plots each measuring 30 x 30 m and recorded nest sites of 13 ant species. We found that NDVI values at the nesting sites varied considerably between individual species and also between the six functional groups the ants belong to. The functional groups Cryptic Species, Tropical Climate Specialists and Specialist Predators were present in regions with high NDVI whereas Hot Climate Specialists and Opportunists were found in sites with low NDVI. As expected we found that low NDVI values were associated with scrub jungles and high NDVI values with evergreen forests. Interestingly, we found that *Pachycondyla rufipes*, an ant species found only in deciduous and evergreen forests, established nests only in sites with low NDVI (range = 0.015 - 0.1779). Our results show that these low NDVI values in deciduous and evergreen forests correspond to canopy gaps in otherwise closed deciduous and evergreen forests. Subsequent fieldwork confirmed the observed high prevalence of *P. rufipes* in these NDVI-constrained areas. We discuss the value of using NDVI for the remote detection and distinction of ant nest sites.

Keywords: ants, NDVI, nest site selection, Western Ghats, canopy gap, *Pachycondyla rufipes*

INTRODUCTION

Information about ecological and geographical distribution of species is essential to understand spatial patterns of biodiversity and to chalk out robust conservation strategies (Rushton *et al.* 2004; Graham *et al.* 2006). However, for most species, the number and spatial density of confirmed occurrences is very low. Hence ecologists use species distribution models in an

attempt to provide predictions of distribution of species over large areas by relating presence/absence or density of flora and fauna to environmental predictors (Elith *et al.* 2006). These species distribution models are typically built using the ecological niche concept (Hutchinson 1957). An ecological niche of a particular species is defined by long-term stable constraints on the potential of its geographic distribution such as habitat suitability. Ecological niche modeling

techniques quantify and exploit such constraints (Peterson 2003) and comprehensive reviews of the available species distribution modeling approaches have been provided by Guisan & Zimmermann (2000) and Elith *et al.* (2006). Aggregating results of several species distribution models can improve our understanding of the relationship between environmental parameters and species richness (MacNally & Fleishman 2004). Other potential application areas include research into the ecological and geographical differentiation of distribution of congeneric species (Cicero 2004; Graham *et al.* 2004), and investigations of the invasive potential of non-native species (Peterson 2003; Goolsby 2004; birds: Peterson & Vieglais 2001; Fuller *et al.* 2007; plants: Panetta & Dodd 1987; insects: Eyre *et al.* 2004; Roura-Pascual *et al.* 2006). Regardless of the intended application area and the choice of modeling algorithm model reliability is determined to a large degree by the quality of the input data. The present study intends to augment our knowledge in this field by exploring the potential of the Normalised Difference Vegetation Index (NDVI) data, derived from the Linear Imaging Self-scanning Sensor (LISS) on the Indian Remote sensing Satellite IRS-1D, to distinguish between habitat types used by a variety of ant species to build their nests. This analysis is performed at (a) the level of functional groups and (b) species level. Furthermore, we use these remotely sensed data to investigate the prevalence of *Pachycondyla rufipes* nest sites within the area identified as suitable in terms of NDVI, which supports our interpretation of this species' peculiar choice of nesting site.

The rationale for investigating the potential of NDVI as a discriminatory variable for ant nest site allocation is the assumption that ants consider vegetation characteristics when establishing nests, and NDVI is one of the commonly used vegetation indices. NDVI is calculated from the reflectance values in the red and near infrared electromagnetic spectrum. NDVI thus quantifies chlorophyll activity of plants by relating the absorption of light at wavelengths of around 0.6 – 0.7 μm (red) to the reflection of light at wavelengths of around 0.7 – 0.9 μm (near infra-red). Vegetation with high chlorophyll activity is characterized by large NDVI values, which may indicate high greenness, high biomass or both. After taking into account sub-vegetation ground reflectance properties and some

other additional factors, a basic delineation of vegetative from non-vegetative land cover features may also be achieved (Lillesand *et al.* 2004).

The use of LISS-derived NDVI data allows us to exploit two major advantages of remotely sensed data. First is the fast capture and consistent representation of NDVI values across a fairly large area, especially when temporal variability is taken into account, e.g. by conducting a time series analysis. Second, available remote sensing data continues to increase in spatial resolution, which is an essential prerequisite for building models at a scale appropriate for the studied organism. LISS-derived NDVI products feature an acceptable fine spatial resolution for the purposes of this study.

NDVI has been used as predictor variable in several studies: to determine the extent of vegetation cover (Narendra 2000), to monitor productivity and health of an ecosystem (Zhang *et al.* 1997; Ikeda *et al.* 1999), to determine outbreaks of insects (Leckie *et al.* 1992), to map crop conditions of agricultural fields (Brewster *et al.* 1999) and to characterise the structure of forest canopies (Gamon *et al.* 1995; Wannebo & Rosenzweig 2003). NDVI has previously been used in determining the ecological habitat requirements of an invasive ant species, and its correlation with ant presence was found to be quite consistent (Roura-Pascual *et al.* 2006). However, in the above study NDVI was used in conjunction with another vegetation index (EVI) and topographical variables, i.e. the individual potential of NDVI was not assessed. In this study, we analyse the relation between LISS-derived NDVI alone and the location of nesting sites of different ant species.

MATERIALS AND METHODS

Study area

The study was carried out in the Sharavathi River Basin (13°43'24 - 14°11'57N to 74°40'58 - 75°18'34E) located in the Central Western Ghats, Karnataka, India (Fig. 1). The river basin covers a total area of 1991.43 km² with the Western region receiving ~2500 mm of annual rainfall and the eastern region ~900 mm (ShivalingaMurthy 2008). The vegetation, similar to elsewhere in the Western Ghats, is a mosaic of evergreen forests, moist- and dry-deciduous forests and scrub jungles interspersed with plantations of *Acacia* sp.

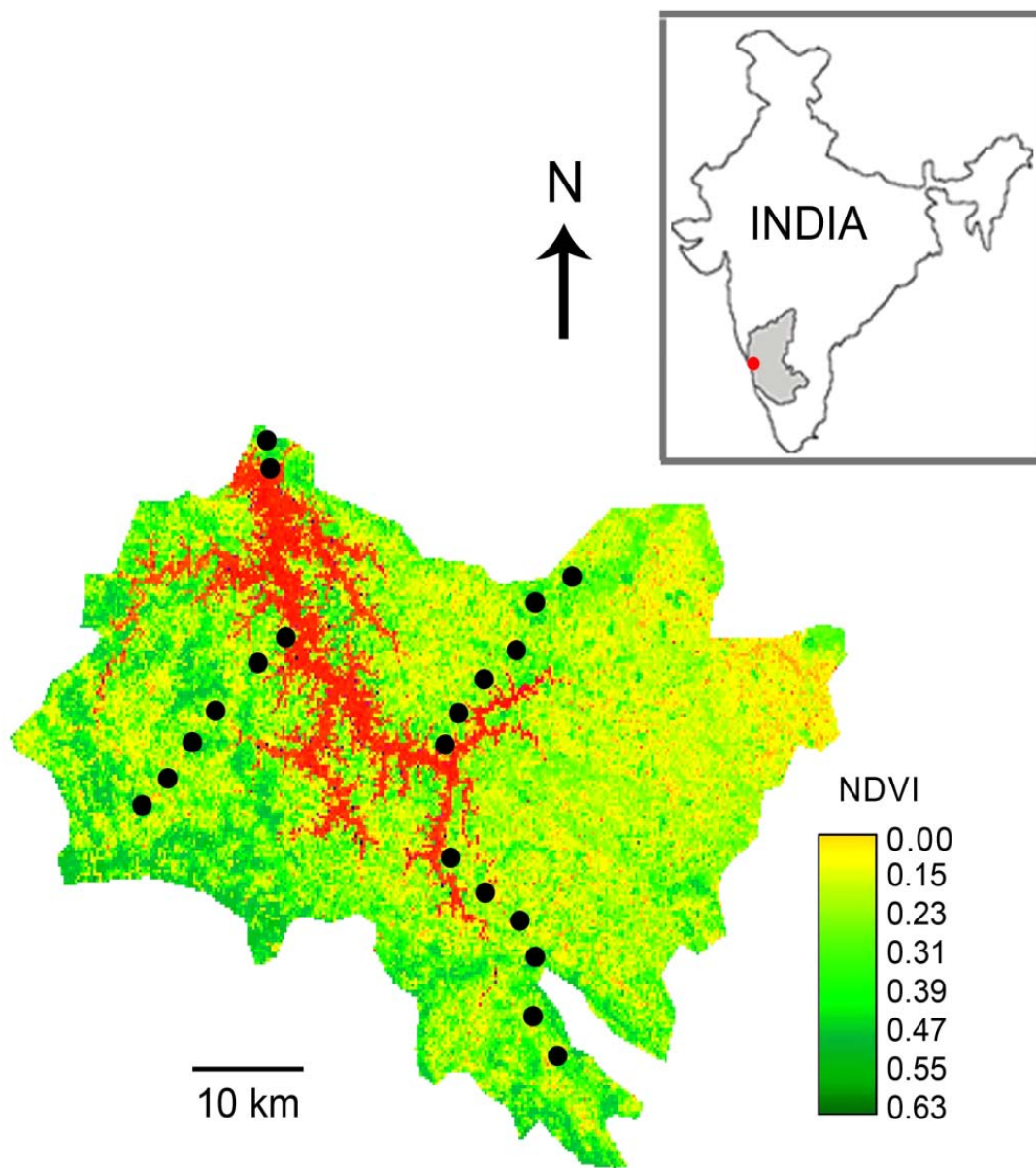


Fig. 1. Location of the study area, sampling points and the greenness of the region determined by the Normalised Difference Vegetation Index (NDVI). Inset shows the location of the study area (*red dot*) in the state of Karnataka (*shaded grey*) within India. Sampling locations (filled circles) along the North, South, East and West are shown in the study region. Each location comprised three sampling plots measuring 30 x 30 m (see Methods). Vegetation is shown in varying intensities of green and water is shown in red. Very low values of NDVI (<0.2) correspond to barren areas such as rocky outcrops and wasteland. Moderate values (0.2 to 0.3) represent scrub jungle and grassland, while high values (>0.4) indicate deciduous and evergreen forest.

Taxonomy

The study area provides habitat for 93 species of ants representing 36 genera (Narendra *et al.* in review). Of these we here focus on the nesting site characteristics of 13 species that represent the major functional groups in this region (Narendra *et al.* in review): Generalised Myrmicinae (represented by *Myrmecaria brunnea* Saunders, *Crematogaster* sp. 1, *Pheidole* sp. 2), Tropical Climate Specialists (*Cataulacus taprobanae* Smith, *Oecophylla smaragdina* (Fabr.)), Specialist Predators (*Harpegnathos saltator* Jerdon, *Leptogenys processionalis* (Jerdon), *Pachycondyla rufipes* (Jerdon)), Opportunists (*Anoplolepis gracilipes* (Smith), *Paratrechina longicornis* (Latr.), *Technomyrmex albipes* (Smith)), Hot Climate Specialists (*Meranoplus bicolor* (Guérin-Méneville)) and Cryptic Species (*Pheidologeton diversus* (Jerdon)). Species designation to functional groups was carried out following Brown's (2000) detailed distribution, biology and ecology of world ant genera.

Ant sampling techniques

We sampled along three 20 km transects along South, East and West sides of the reservoir and one 4 km transect along the North side of the reservoir (Fig. 1). The transect towards the North was short as it was close to the reservoir. At 4 km intervals along each transect we established three sampling plots, each measuring 30 x 30 m. These plots were along a mini-transect at 200 m intervals and set perpendicular to the main transect. This resulted in a total of 60 sampling plots, distributed across five forest types: scrub jungles, acacia plantations, dry deciduous forests, moist deciduous forests and evergreen forests.

Between 2000 and 2002 we located nest sites of the 13 focal ant species in each sampling plot. A systematic visual sampling was carried out at each plot during 09:00-11:00 h and 15:00-17:00 h which involved checking under tree bark, rotting logs and leaf litter. To increase our chances of locating the nest we set up terrestrial and arboreal bait traps and followed either the ant trail or individual foragers that were returning to the nest with food. Baits consisting of 70% honey, tuna fish and fried coconut were provided as both terrestrial and

arboreal baits. Terrestrial baits were placed on the ground and the arboreal baits were tied to a tree at a height of two metres from the ground. The bait traps were laid at 07:00 h and retrieved at 17:00 h. The baits were checked once every 30 minutes and ants that had visited the bait were recorded and their nests were located. Presence or absence of nests of each of the 13 species was determined by a one-time sampling at each of the 60 plots. Ants collected from the two methods were sorted, cleaned in saltwater solution, preserved in 70% ethyl alcohol and identified using keys provided by Bingham (1903) and Bolton (1994). Scientific names are based on the current nomenclature (Bolton 1995) and were cross verified with the online ant database (Agosti & Johnson 2005). Specimens have been deposited at the Insect Museum, Centre for Ecological Sciences, Indian Institute of Science.

Remote sensing data

We used a single cloud-free multispectral satellite image acquired on 5 March 1999 (Path 97 – Row 63) captured by the Linear Imaging Self-scanning Sensor (LISS) onboard the Indian Remote sensing Satellite IRS-1D. Data were purchased from the National Remote Sensing Agency, Hyderabad, India. The image covers the entire study area. Bands 2 and 3 (VIS: 0.62 – 0.68; NIR: 0.77 – 0.86) were extracted and geo-referenced by means of ground control points, established during fieldwork using a GPS receiver. Both bands feature a spatial resolution of 23.5 m. Our use of the satellite imagery acquired before the sampling period is justifiable, since land cover in this region had not changed significantly between these two dates. Evidence for this comes from our analysis of 2002 satellite imagery for this region (unpublished results).

NDVI as surrogate for vegetation status

From these two bands we calculated the NDVI following the established formula:

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$$

(Lillesand *et al.* 2004). Using NDVI as a surrogate for vegetation status in this region is justifiable since the terrain in this region is very hilly and NDVI is one of the vegetation indices that

minimises topographic effects in vegetated areas (Lillesand *et al.* 2004). Its value ranges from -1 to $+1$; negative or near-zero values indicate non-vegetated areas (e.g. soil, water), while positive values represent vegetated areas.

Analyses

We identified five major habitats, without using remote sensing data, to sample ants. Our first question was hence to assess the correlation between LISS-derived NDVI values at the visited ant nest sites and the five habitat types. Our motivation behind this was to validate the remotely sensed NDVI data as a descriptor of the pre-defined habitat types, before using it in support of our interpretation of the relationship between ant nest site choice and habitat type. To evaluate this correlation, we extracted the NDVI values from all nest sites using GIS software, grouped all ant nest sites according to their designated habitat type, and carried out an analysis of variance (ANOVA) of the corresponding NDVI values followed by a post-hoc Tukey test to assess whether differences in NDVI were significant between these groups.

Our second question was to find out whether the ant functional groups to which the 13 species belong establish their nests at locations characterised by different NDVI values. To test this we grouped ant nest sites according to their designated functional group (Brown 2000; also see Andersen 1995, 2000). We then carried out an analysis of variance (ANOVA) of the associated NDVI values, followed by a post-hoc Tukey test to assess whether differences in NDVI were significant between these groups.

Our third question was to test whether differences in NDVI values associated with ant nesting locations were distinct at the species level. To test this we carried out the same analysis as for the functional groups using nest site NDVI values grouped at species level.

Our fourth question was established in response to the results we obtained from the three analyses above. Most ant nests were found to be associated with NDVI values that corresponded well with the expected habitat type for the species (see results section for details). For one of the 13 species, *Pachycondyla rufipes*, we obtained nest

site NDVI values that were surprisingly low and did not match the NDVI range of the habitat type in which the species occurred. We tested this against the NDVI values observed at all other nest-sites.

To consolidate our interpretation of this result (see discussion section for details), we conducted an assessment of the robustness of *P. rufipes* prevalence in this NDVI range using independent data obtained from additional fieldwork. We randomly selected 25 locations from previously un-sampled regions with NDVI values in the same range in which we had found *P. rufipes* nests before (0.015 – 0.1779) and conducted a visual all-out search for the nests of this species at these sites. Due to topographical limitations only 17 of the 25 plots were visited. Next, we calculated the respective prevalence value for our original dataset, using only those locations, which featured NDVI values within the same range (0.015 – 0.1779). We then compared both values to assess whether the difference in prevalence was significant. Non-parametric tests were used when data was not normally distributed.

RESULTS

Our first analysis shows that LISS-derived NDVI values mirror the general trend in supposedly increasing biomass from scrub jungle to evergreen forest ($P < 0.001$; $F_{4,53} = 6.5322$, ANOVA; Fig. 2). Evergreen forests habitats had NDVI values that differed significantly from all habitats except moist deciduous forests. NDVI values between scrub jungles and moist deciduous forests were also significantly different.

Nest site NDVI at the level of functional groups was significantly different ($P < 0.001$, $F_{5,106} = 14.1029$, ANOVA; Fig. 3). Hot Climate Specialists and Opportunists occupied a narrow range of NDVI niche, while Generalised Myrmicinae occupied the broadest range. Post-hoc tests revealed that NDVI at the nest sites of Tropical Climate Specialists, Cryptic Species and Specialist Predators did not differ and were comparatively high (Fig. 3). NDVI at nest sites of Opportunists were significantly different from nest sites of Cryptic Species, Specialist Predators and Tropical Climate Specialists but were similar to Generalised Myrmicinae. NDVI at nest sites of Hot

Climate Specialists were comparatively low and were found to be similar to the niche occupied by Opportunists and Generalised Myrmicinae. Our results suggest that in terms of NDVI the Opportunists and Hot Climate Specialists group occupy a very narrow niche within the broad habitat range of Generalised Myrmicinae (Fig. 3).

Analysis of nest site NDVI at the species level revealed large differences ($P < 0.001$, $F_{12,118}=9.2476$, ANOVA; Fig. 4). Nesting sites of *C. taprobanae*, *O. smaragdina*, *H. saltator*, *L. processionalis* and *P. diversus* were found in areas with a high mean and an intermediate variance in NDVI. Nesting sites of *Crematogaster* sp. 1, *Pheidole* sp. 2 and *M. brunnea* exhibited an intermediate mean and a particular high variance in NDVI. Nesting sites of *A. gracilipes*, *P. longicornis*, *T. albipes* and *M. bicolor* were found

in areas with a low mean in NDVI and these species displayed the lowest variance in NDVI at their nest sites.

The above findings reflect fairly well the habitat preferences of the studied ant species – except for one of the specialist predators, *Pachycondyla rufipes* (Fig. 5), whose nest sites showed surprisingly low NDVI values ($0.09 \pm .069$; mean \pm SD; $n=11$) and differed significantly ($P < 0.05$; $t = -2.046$; t -test) from the ensemble NDVI of all other nest sites examined (0.201 ± 0.106 ; mean \pm SD; $n = 49$). The nest site NDVI analysis suggests that *P. rufipes* prefers to nest in scrub jungle – a completely unexpected result, since we collected *P. rufipes* only from deciduous and evergreen forests, but never from scrub jungles or acacia plantations. In the search for an explanation we realized that previously we had observed the

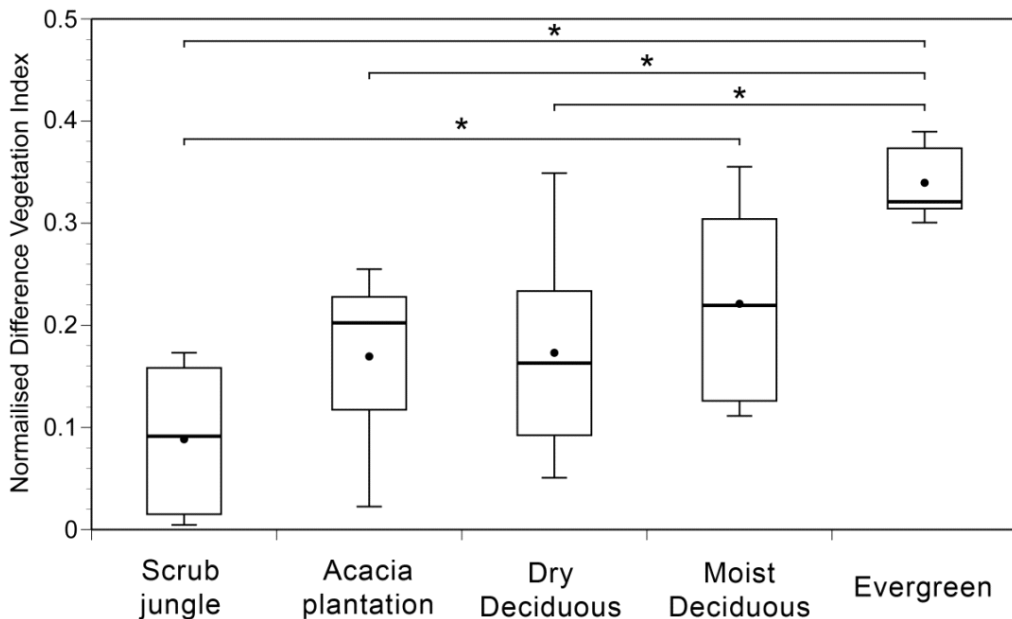


Fig. 2. Box plot illustrating the variation of NDVI in different habitats. Each box shows upper and lower quartiles along with 90th and 10th percentiles (whiskers), median (thick line) and mean (filled circle). NDVI values are shown on the y-axis. The different habitats are shown on the x-axis: Scrub Jungle ($n=8$), Acacia Plantation ($n=10$), Dry Deciduous ($n=13$), Moist Deciduous ($n=24$) and Evergreen forest ($n=5$). NDVI values at nest sites in the five habitats were significantly different ($P < 0.001$). Pairs that are significantly different are highlighted with * ($P < 0.05$, Tukey test).

nesting locations of *P. rufipes* to be in dense vegetation patches that had large gaps in the canopy. We wondered if canopy breaks in dense forests were indeed nesting sites of *P. rufipes* and if these locations could be identified using NDVI. Our subsequent analysis showed that prevalence of *P. rufipes* in the NDVI range in which the species was initially observed (0.015 – 0.1779), was not significantly different between our validation and initial dataset ($P = 0.6223$, $U=28.0$; Mann-Whitney test). In fact, we found *P. rufipes* nests in all of the 17 new locations, which strongly supports our hypothesis of *P. rufipes*' preference for canopy gaps in nest site selection. Our subsequent analysis showed that prevalence of *P. rufipes* in the NDVI range in which the species was initially observed (0.015 – 0.1779), was not significantly different between our validation and initial dataset

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DISCUSSION

The results of this study show that in the Western Ghats, some ant species and even some functional groups establish their nests at locations that can be clearly distinguished using LISS-derived NDVI. However, the discriminative success of NDVI was limited to ant species that nest in areas with low NDVI, i.e. in relatively sparse vegetation. The reason for the failure of NDVI to distinguish ant nesting locations at the species (and functional group) level when they are located in dense

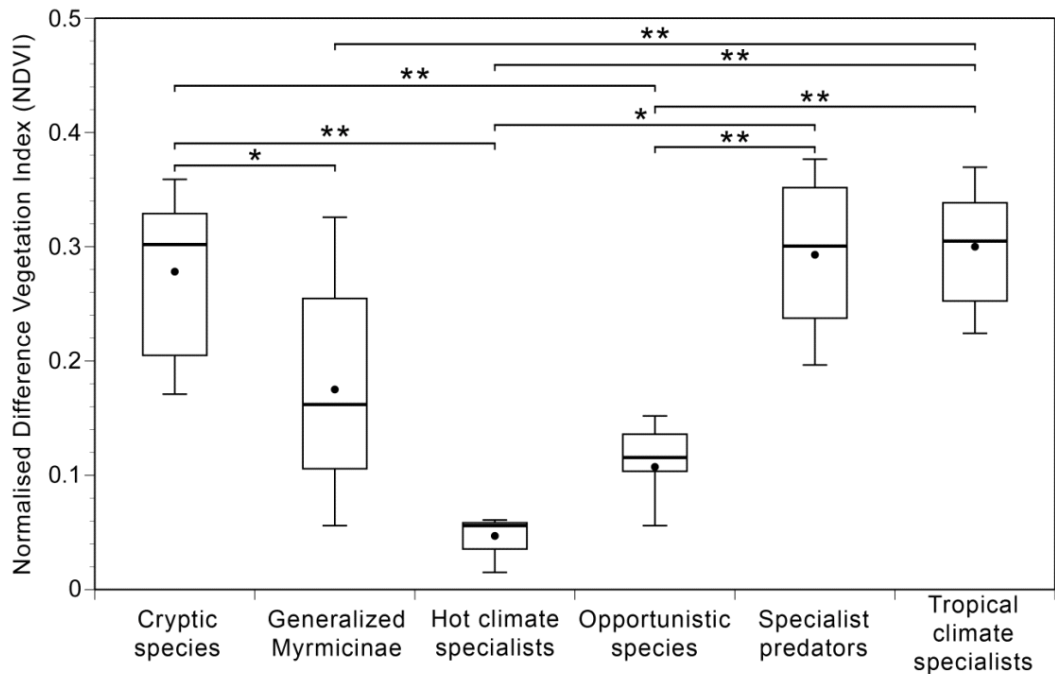


Fig. 3. Box plot illustrating the variation of NDVI at nest locations of six functional groups. Each box shows upper and lower quartiles along with 90th and 10th percentiles (whiskers), median (thick line) and mean (filled circle). NDVI values are shown on y-axis. The six functional groups are shown on x-axis. Note: *Pachycondyla rufipes* has not been included in this functional group analysis. NDVI at the nest sites of the Cryptic Species ($n=14$), Generalised Myrmicinae ($n=59$), Hot Climate Specialists ($n=6$), Opportunistic Species ($n=22$), Specialist Predators ($n=14$) and Tropical Climate Specialists ($n=21$) were significantly different ($P < 0.001$). Pairs that are significantly different are highlighted with * or ** ($P < 0.01$ and $P < 0.001$ respectively, Tukey test).

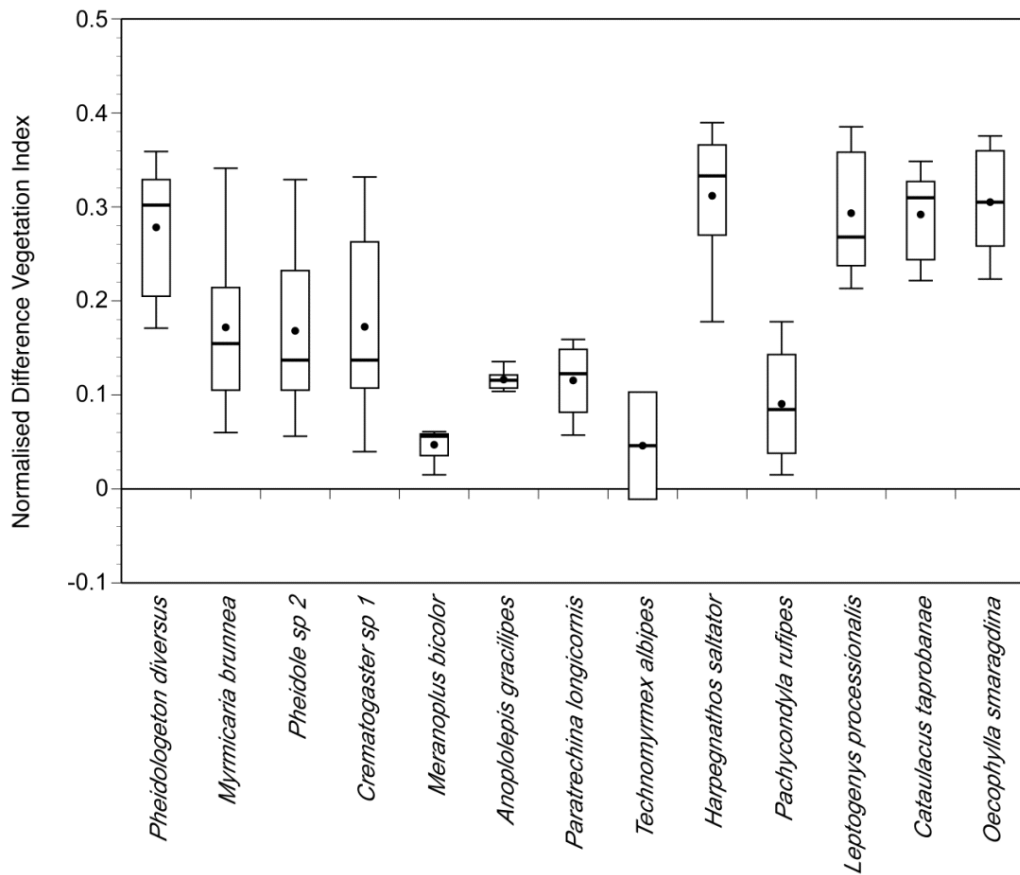


Fig. 4. Box plot illustrating the variation of NDVI at nest locations of 13 species. Each box shows upper and lower quartiles along with 90th and 10th percentiles (whiskers), median (thick line) and mean (filled circle). NDVI values are shown on y-axis. The different species are shown on x-axis. NDVI at the nest sites of *Anoplolepis gracilipes* ($n=9$), *Paratrechina longicornis* ($n=8$), *Technomyrmex albipes* ($n=5$), *Cataulacus taprobanae* ($n=8$), *Oecophylla smaragdina* ($n=13$), *Harpegnathos saltator* ($n=7$), *Pachycondyla rufipes* ($n=11$), *Leptogenys processionalis* ($n=7$), *Crematogaster* sp. 1 ($n=21$), *Pheidole* sp. 2 ($n=25$), *Myrmecaria brunnea* ($n=13$), *Pheidologeton diversus* ($n=14$) and *Meranoplus bicolor* ($n=6$) were significantly different ($P < 0.001$). Tukey test revealed significant differences ($P < 0.01$) between the following pairs: *M. brunnea* vs *O. smaragdina*; *Crematogaster* sp. 1 vs *Pheidole* sp. 2; *Crematogaster* sp. 1 vs *O. smaragdina*; *Crematogaster* sp. 1 vs *P. diversus*; *Pheidole* sp. 2 vs *H. saltator*; *Pheidole* sp. 2 vs *L. processionalis*; *Pheidole* sp. 2 vs *C. taprobanae*; *Pheidole* sp. 2 vs *O. smaragdina*; *Pheidole* sp. 2 vs *P. diversus*; *A. gracilipes* vs *H. saltator*; *A. gracilipes* vs *L. processionalis*; *A. gracilipes* vs *C. taprobanae*; *A. gracilipes* vs *O. smaragdina*; *T. albipes* vs *H. saltator*; *T. albipes* vs *L. processionalis*; *T. albipes* vs *C. taprobanae*; *T. albipes* vs *O. smaragdina*; *T. albipes* vs *P. diversus*; *P. longicornis* vs *L. processionalis*; *P. longicornis* vs *C. taprobanae*; *P. longicornis* vs *O. smaragdina*; *P. longicornis* vs *P. diversus*; *P. longicornis* vs *H. saltator*; *H. saltator* vs *P. rufipes*; *H. saltator* vs *P. diversus*; *H. saltator* vs *M. bicolor*; *P. rufipes* vs *L. processionalis*; *P. rufipes* vs *C. taprobanae*; *P. rufipes* vs *O. smaragdina*; *P. rufipes* vs *P. diversus*; *L. processionalis* vs *M. bicolor*; *C. taprobanae* vs *M. bicolor*; *O. smaragdina* vs *M. bicolor* and *P. diversus* vs *M. bicolor*.

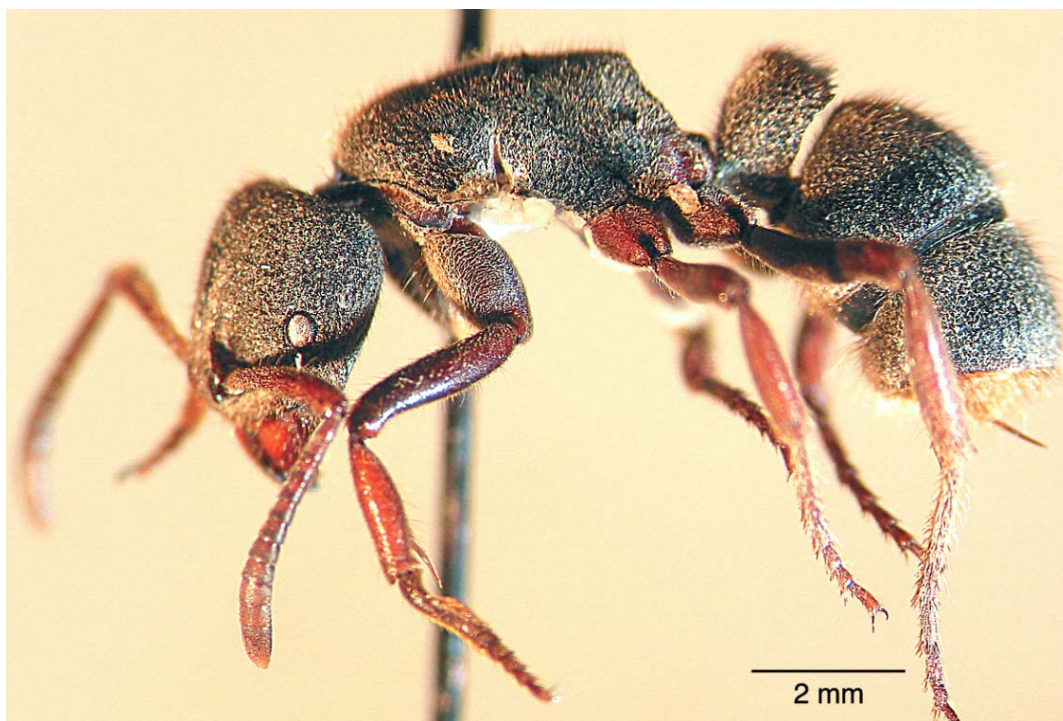


Fig. 5. Profile view of *Pachycondyla rufipes* (Jerdon), an ant that establishes terrestrial nests under canopy gaps in moist deciduous and evergreen forests. Collected at Sharavathi River Basin, Shimoga, Western Ghats, India.

vegetation is probably that in these cases, ant species do share similar habitat in terms of greenness and / or biomass: *H. saltator* and *L. processionalis* are specialist predators on other arthropods and known to inhabit deciduous and evergreen forests; *O. smaragdina* and *C. taprobanae* are arboreal ants that are dominant in humid tropical regions, and *P. diversus* is a cryptic species that nests and forages within soil and leaf litter (Figs. 3, 4). To distinguish nesting sites of such species it might therefore be necessary to use additional variables.

A potential limitation of this study is that our interpretation of the relationship between ant nest sites and habitat type was based on nest-site NDVI only. Although we complemented this with a correlation analysis of NDVI and the pre-defined habitat types, a direct assessment of species-specific nest site frequency vs. habitat type is missing. Regardless of this shortcoming, our

purely NDVI-based analysis results match the documented habitat preferences of species inhabiting areas with less dense vegetation quite well: invasive species such as *A. gracilipes* and *P. longicornis* along with *T. albipes* were abundant in scrub jungles and acacia plantations that have low NDVI (Fig. 4). All three species are Opportunists that exhibit unspecialised food and niche requirements, are poorly competitive, and are dominant in disturbed habitats (Andersen 1995). The seed harvesting ant *M. bicolor* was abundant in regions with low NDVI such as scrub jungles. On the other hand, a particular wide range of NDVI niches were occupied by the ubiquitous species of the myrmicine community (*Crematogaster* sp. 1, *Pheidole* sp. 2 and *M. brunnea*) that do not have highly specific niche requirements (Fig. 4).

A surprising finding was that *P. rufipes*, a specialist predator on termites (Narendra & Kumar

2006), built nests at sites with low NDVI despite the fact that this species was collected only from deciduous and evergreen forests (Fig. 4). Similar observations on the niche occupied by this ant species have been reported (Narendra & Kumar 2006; Narendra *et al.* in review). NDVI at the collection sites of *P. rufipes* was similar to that in the scrub jungles (Fig. 3), a habitat from which this species was never collected. And although our validation fieldwork confirmed the initial observation that both nesting sites and foragers of *P. rufipes* coincided with canopy gaps of deciduous and evergreen forests, the question remains: why is *P. rufipes* found in canopy gaps?

Individually foraging ants rely on direct-ional information gathered either from celestial cues (Wehner 2001) or from landmarks present in the foraging environment (Fukushi 2001; Narendra 2007). Solitary foraging ants are well known for their ability to return to the nest by matching the previously seen views (Wehner & R ber 1979; Narendra *et al.* 2007). In fact a congeneric species of *P. rufipes*, *Pachycondyla tarsata* (Fabr.) (previously known as *Paltothyreus tarsatus*) uses the contrast available in the canopies (H lldobler 1980) to match its previously acquired image to its current images to return to the nest. In the landmark-rich habitats of *P. rufipes* it is quite unlikely for individual trees to act as a beacon and utilisation of celestial cues may be hindered. It is perhaps because of this that *P. rufipes* colonises canopy gaps, a micro-niche that would enable the ants to forage using information derived from both canopies and sky.

The example of *P. rufipes* demonstrates the potential of high-resolution remotely sensed NDVI data in delineating preferred nesting sites for species whose habitat preferences are clearly different from those of other ant species in the study area, in terms of both density and geometry of the local vegetation. It does not however shed much light on the potential of NDVI as a predictor variable to model ant species distributions, as this would require validating results for each species at random locations from anywhere in the study area and not only from within the high-probability range. Also, if NDVI was to be tested as predictor variable for presence of *P. rufipes* nests, we would recommend to not only employ the absolute value but also a derived variable that quantifies the

difference in NDVI between neighbouring pixels, i.e. taking into account the ‘‘canopy gap’’ as an argument for habitat suitability. We emphasise that our study did not intend to validate the pre-defined habitat categories using remotely sensed NDVI; instead, we merely assessed the correlative strength between these two at the selected nest sites. It would be interesting however, to use the LISS-derived NDVI image to establish habitat types for the whole study area (e.g. by means of a supervised classification) and then explore the relationship between ant nest site locations and habitat type at both the species and the functional group level.

We conclude that LISS-derived NDVI has considerable value in deriving the nest site locations of some ant functional groups and even at species level, especially regarding ant species that belong to the functional groups Hot Climate Specialists and Opportunists. These results are encouraging for decision-makers dealing with invasive species, which are often opportunistic. Officers in the land-use and conservation sector who need to monitor the effects of intensifying human land-use and climate change stand to benefit as well, since many ant species are considered reliable indicators for ecosystem change.

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