Variation in plant functional traits across contrasting habitats in a seasonally dry tropical forest in the Northern Western Ghats.

Thesis submitted towards the partial fulfilment of

BS-MS Dual degree programme

By

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Certificate

This is to certify that this dissertation entitled “Variation in plant functional traits across contrasting habitats in a seasonally dry tropical forest in the Northern Western Ghats” towards the partial fulfilment of the BS-MS dual degree programme at the Indian Institute of Science Education and Research (IISER), Pune represents original research carried out by Asmi Jezeera M, at IISER Pune under the supervision of Dr. Deepak Barua, Assistant Professor, Biology Division, IISER Pune during the academic year 2015-2016.

Date: 28th March 2016

Signature of the Supervisor
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Declaration

I hereby declare that the matter embodied in the thesis entitled “Variation in plant functional traits across contrasting habitats in a seasonally dry tropical forest in the Northern Western Ghats” is the result of the investigations carried out by me at the Biology division, IISER Pune under the supervision of Dr. Deepak Barua and the same has not been submitted elsewhere for any other degree.

Date: 28th March 2016

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Abstract

Functional traits are measurable traits which infers about plant response to different environmental cues. Functional traits are measured at the level of an individual, but give an opportunity to scale up the study to the level of population or communities or ecosystem. Functional trait studies help us to understand community processes like community assembly processes, species distribution pattern etc. This study tried to examine the intra-specific variation of leaf functional traits across the three habitats (open, edge and closed). The next objective was to understand how CWM and FD change across the three habitats and to understand the relative contribution of intra-specific variation and species turn over in the observed variation of CWM and FD. The leaf functional traits of the species studied were significantly different. For the species which were present in more than one habitat, there was considerable intra-specific variation in different habitat pairs. Functional traits at the community level showed better reflection of the environmental gradient than the diversity indices. CWM and FD of LA and LMA varied significantly across open & edge and open and closed habitats whereas the CWMs were not significantly different between edge and closed. The CWM and FD of LDMC was not significant. There was significant contribution of intra-specific variation in the observed variation of CWM and FD across the three habitats. There was a sharp difference in the contribution of intra-specific to inter-specific variation to CWM and FD between different habitat pairs within the community.

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Introduction:

Tropical forests have been receiving a great deal of attention in the last decade on the light of the fragmentation, deforestation and global temperature change. But as compared to Savanna and wet forests, information about dry tropical forests is less though there is an increase in the number of studies in tropics in the recent past. Tropical dry and moist forests comprise a major share of the forest area in India in which tropical dry deciduous and tropical dry evergreen forest comprises 28.8% (26.6% and 0.2% respectively) of the total forest area (Champion and Seth, 1968). For any sort of conservation efforts, an inventory of the structure and composition of the different forests are necessary. But, community structure and composition is the product of multiple interacting factors including mean annual temperature, mean annual rainfall, duration of dry season, soil topography etc. So, it is better effective to get information at the level of specific localities. This helps to gather information on endemic species of particular area, geographic affinities of different species or functional types (Killeen *et al.*, 1988) as well as distribution pattern of different life forms or species. There are few studies describing the forests of peninsular India with fewer studies describing the dry forests of northern Western Ghats (Dexter *et al.*, 2015). These studies describe the forests based on the structure and species composition (Anbarashan and Parthasarathy 2008, 2013, Ayyappan and Parthasarathy 2001, Chittibabu and Parthasarathy 2000, Mani and Parthasarathy 2005, Muthuramkumar *et al.*. 2006) where the taxonomic identity of the plant is important. But, last few decades saw an emergence in the field of functional ecology. This approach uses biological characteristics (measurable traits) along with species identity to describe the communities (Lavorel *et al.*, 1997; Violle *et al.*, 2007)

Plants may follow different strategies in different environment to adjust with the environment and to coexist with other species. A major aspect of plant ecology is to identify and understand these strategies. Quantitative measure of certain traits can give insight into the plant strategies in different habitat or environment or climate. These traits, functional traits, can be any measurable trait including morphological, biochemical, physiological, structural, phenological, or behavioral traits but helps to infer about the fitness of the individual in a particular environment (Westoby, 2002; Violle *et al.*, 2007). The major functional traits which are majorly studies are leaf functional traits (Leaf Area, Leaf Mass per Area, Leaf Longevity, Leaf Dry Matter Content etc), seed functional traits (Seed Mass, Seed Number and Seed Dimensions), plant height etc. Physiology and performance of a plant can be inferred from functional traits, hence was used as a tool to create a link between physiology and performance of the plant in different environments (Poorter and Bongers, 2006). Functional traits are influenced by the habitat and thereby used in field as well as controlled experiments to understand the effect of different abiotic and biotic factors on plants (Reich *et al.*, 1999; Wright *et al.*, 2004; Wright *et al.*, 2005). They are also widely used in climate change models (Verheijen *et al.*., 2015) as functional traits can be used to infer about the response of plants to climate change (Ordoñez *et al.*., 2009). They are also being used to understand the effect of land use changes in the vegetation (Garnier *et al.*, 2007).

Wright *et al.*, 2004 described leaf economic spectrum by bringing together different plant functional traits including structural, chemical and physiological traits of different life forms. Leaf economic spectrum throws light on different energy and nutrient allocation of plants in response to environmental cues like mean annual temperature, mean annual temperature etc (Wright *et al.*, 2004). Functional traits and trait pair relationships help to get an idea of different tradeoffs. Leaf area (LA) is often related to environmental factors like light, water availability etc (Wright *et al*., 2005). LA gives insights about the space available for photosynthesis, transpiration and light interception (Westoby *et al.*, 2002). Hence, studies about LA helps to understand about plant strategies to maximize photosynthesis in a particular environment by optimizing the tradeoff between leaf area (light interception) and water loss by transpiration (Westoby *et al.*, 2002). Leaf Mass per Area (LMA) is an important trait in plant growth (Poorter etal, 99). It is widely used in many fields such as plant ecology, physiology, agriculture, forestry etc as it is a key indicator of plant strategies (Westoby etal, 2002). LMA is also dependent on abiotic factors like water and light availability (Rozendaal *et al*., 2006) and changes in the opposite direction of leaf area (Westoby *et al.*, 2002). LMA can be defined as the dry mass investment by the plant for photosynthesis and light interception per leaf area (Westoby, 2002; Wright *et al*., 2005). High LMA means high investment by plant, hence high LMA leaves have high Leaf Longevity (LL) as per leaf lifespan theory by Kikuzawa (Westoby *et al.*,2002). So, LMA and LL together help us to understand the net energy gain by the plant as LMA shows cost of construction and maintenance whereas LL shows the duration of photosynthetic return from the plant, ie, the gain (Westoby, 2002; Wright *et al.*, 2005). This direct relationship between LMA and LL has been shown by different studies indicating slow nutrient turnover rate for high LMA leaves (Westoby *et al.*, 2002). Slow nutrient turnover means that species with high LMA leaves have a higher nutrient reserve in them as compared to species with low LMA leaves. Mostly studied leaf traits regarding nutrients are Leaf Carbon Content (LCC), Leaf Nitrogen Content (LNC) and Leaf Phosphorous Content (LPC). LCC helps to infer about the investment of the plant in structural support where as LPC indicates about the plant investment in nucleic acids, lipid membrane and energy molecules like ATP, GTP etc (Wright *et al*., 2005). LNC refers to the plant investment in photosynthetic machinery as the nitrogen is an essential component of proteins of photosynthetic machinery, for example, Rubisco (Wright *et al*., 2005). LMA and LNC have an inverse relationship whereas LNC and Leaf photosynthetic capacity (A_{mass}) are directly related (Wright *et al*., 2005). Leaf Dry Matter Content is the ratio of leaf dry weight to saturated fresh weight. LDMC can be used to infer about leaf density (Garnier et al., 2013). Domínguez et al., 2012, identifies LDMC as a measure of cellular metabolism.

As traits can be used to relate a plant's fitness to a particular environment, trait based approaches are increasingly used to understand the distribution of traits in different environmental gradient such as water, light (Carlucci *et al.*, 2015) rainfall (McLean *et al.*2014), altitude (Jung *et al.,* 2011), soil topography (Bernard-Verdier *et al.,*2012*;* Siefert *et al*.,2014) etc. These studies helped to understand how the different gradients and their interactions affect the trait values and thereby the plant response. Trait based approaches are used to understand and predict the response of the communities to changing environmental conditions (Lavorel and Garnier, 2002; McGill *et al.*, 2006; Leps *et al.*, 2011; Siefert *et al.*, 2014). The contribution of different environmental filters on community assembly can be understood by studying the trait distribution within and across communities along an environmental gradient (Violle etal, 2012). Hence, trait based approaches are being increasingly used to understand the mechanisms behind community assembly (Ackerly and Cornwell, 2007, Webb *et al.*, 2010). The two main processes which are studied in these studies are habitat filtering (increase trait similarity as the filter allows only species within a narrow range of trait values to establish in a habitat) and internal filters (competitive interaction s which limit the similarity of traits of coexisting species) (Ackerly and Cornell, 2009; Jung *et al.*, 2010).

Most accepted approach in community was based on mean field theory (McGill *et al.*, 2006). Garnier et al, 2001, proposed that the species trait values are consistent. This explains assumption in functional ecology that intra-specific variation is much less when compared to inter-specific variation (McGill et al, 2006). Many of the studies were limited by a factor as most studies assigned single mean trait value for a species and thereby neglecting the intra-specific variation associated with the species (Leps *et al.*, 2011). But, trait values are not constant with space and time (Bolnick et al., 2011; Violle et al., 2014). Albert *et al*.,2011, showed that intra-specific variation can be found in individual, population and community level. Intra-specific variation can arise due to plasticity or due to genetic variation or as a result of both (Albert *et al*.,2011). But, Violle *et al.*, 2012 showed the importance of including intra-specific variation in studies regarding community assembly processes. The relative importance of intra-specific variation to inter-specific variation is being studied (Albert *et al*., 2010). Studies including modeling have shown that incorporating of intra-specific variation improves the prediction of biodiversity at local scale (Yamauchi *et al.*, 2009). Jung *et al*., 2010 shows that inclusion of intra-specific variation improves the prediction of the models about the species composition in a community. Hence, the traits can vary from individuals to populations with respect to difference in environment and climate (Aitken & Whitlock, 2013).

There are multiple studies which showed relation between environmental gradients and plant functional traits (Wright *et al.*, 2004; Wright *et al.*, 2005). Here, all species are treated equally. But the relative abundance of the species also plays an important role in response of the communities to the environment as it is known that traits of dominant species has an important role in shaping the response of the community to environment (Ackerly *et al.*, 2002). Hence, it is better to consider the relative dominance or density of the species and weigh the trait values by relative dominance or relative cover of the species in the community to get a better understanding of the effect of environmental gradient on plant communities. Community weighted mean (CWM) is the summation of the species mean trait value weighted by the relative abundance or relative coverage of the species (Garnier *et al.*, 2004; Violle *et al.*, 2007; Siefert *et al.*, 2014). So, there is emphasize is on the individuals rather than species as trait value of all individuals are taken into account for community weighted mean. Carmona *et al*., 2015 shows different sampling methods for calculating CWM. The methods differ in the way the mean trait value is taken. Difference between CWMs of two communities may be because of two reasons, namely species turnover and intra-specific variation. But many of the studies consider only variation between species as a single mean trait value was used for a species for all the communities where the species is present (Kraft *et al.*, 2008). These studies are ignoring the potential effect of intra-specific variation in CWM. There are studies which has found that intra-specific variation contribute significantly to the observed changes in CWMs across environmental gradients (Jung *et al.*, 2010; Leps *et al.*, 2011; Carmona *et al.*, 2015; Siefert *et al.*, 2014). For example, Jung *et al.*, 2010, found 44% of the variation observed in the CWMs across a flooding gradient was explained by intra-specific variation.

Functional diversity gives a measure of biodiversity and gives inference about species dynamics and coexistence and ecosystem functioning (Diaz and Cabido 2001). FD can be defined as the variation of traits between organisms within and across communities. That means, it shows extend of dissimilarity of traits among individuals in a community. FD also helps to understand the different community assembly processes as community assembly is a competition between two filters namely, habitat filter and niche Partitioning which leads to decrease and increase in FD respectively (Cornwell and Ackerly, 2009). There are multiple indices which measures functional diversity, mostly classified as indices measuring functional richness, evenness and divergence. FD can be studies at multiple scales ranging from populations to ecosystem (Lamanna, *et al*.

2014; Violle *et al*., 2012). But, most of these indices do not take into account with in species variability as mean trait value is used to calculate FD (Leps *et al*., 2006). Studies show the importance of incorporating intra-specific variation in FD by demonstrating the difference between the FD indices with and without including individual level variation (Cianciaruso *et al*., 2009). Intra- specific variation accounts for a large amount of explained variability within communities (Jung *et al*., 2014; Siefert *et al*., 2015).

The study system has three different habitats in a gradient of light and water. First objective of the project was to characterize the different (three) habitats in the gradient of light and water both in terms of biotic and abiotic factors. The next objective was to understand the intra-specific variation of functional traits between the three habitats. From the previous studies we know that LMA and LDMC of the species increase as we move from dry to wet areas whereas LA decreases in the same gradient. The functional traits of the edge habitat are expected to be an intermediate of trait values of open and closed habitat. We are interested in knowing whether the intra-specific variation is consistent with the expected direction. It is equally valid to know whether the species are behaving consistently across the different habitats. The next objective was to quantify the variation of CWM and FD across the three habitats. The last objective of the study was to understand the relative contribution of intra-specific variation to species turnover in the observed difference in the CWM and FD across the different habitats

Materials and methods

Study Area: The study was conducted in Bhimashankar Wildlife Sanctuary (BWS) which is located in the Northern Western Ghats (19.1320° N, 73.5540° E) and has a protected area of 131 km^2 harboring species from dry deciduous to wet evergreen. BWS receives an annual rainfall of nearly 3000mm mostly during the months of monsoon from May to September. The average temperature ranges from 36˚C in May to 7˚C in December. The western part of the community consists of three distinct habitats namely, open, edge (intermediate) and closed, out of which open and valley are the most extreme habitat types of the whole community (Fig 1). Crest forests are defined by high light intensity; 30%-70% tree cover, low water availability or low soil moisture content (SMC) and short height trees (2-5 m). Gallery forests or the valley

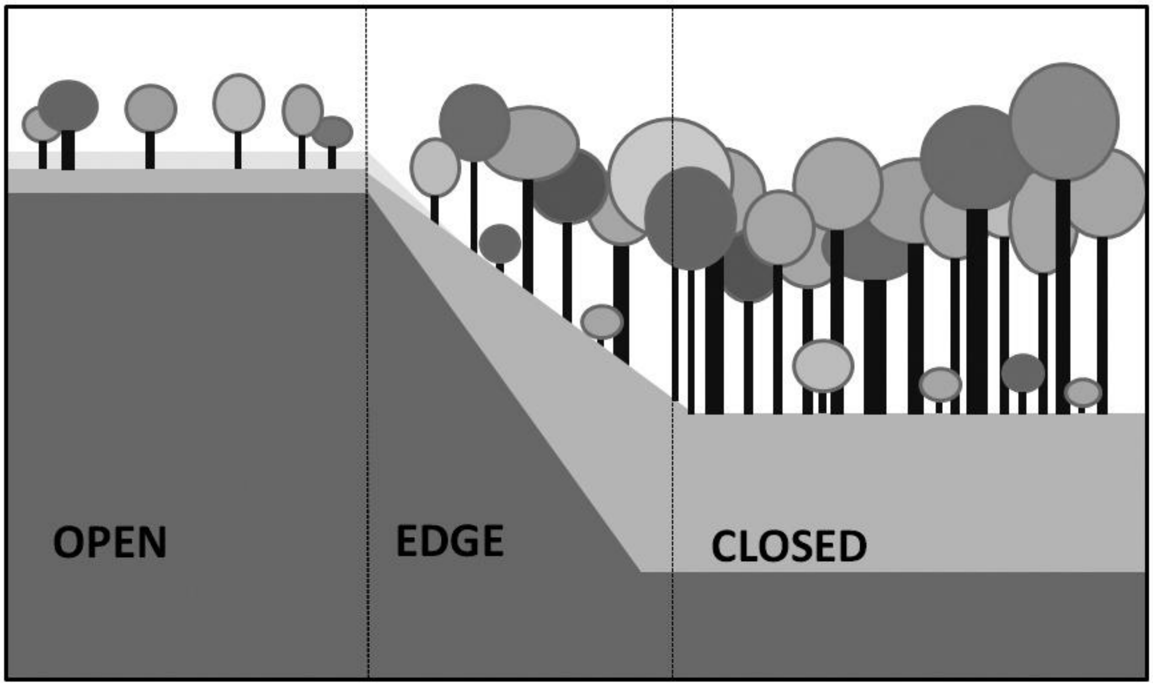


Fig 1: Schematic of the study area showing the three different habitats: open, edge and closed forests.

forests can be defined as those forest areas with low light intensity, high tree cover (90-100%), high soil moisture or high water availability and tall statured trees (10-30m). The intermediate forests (mostly along the slopes) range in between the Crest forest and Gallery forest in terms of its characteristics. They have above 70% tree cover, moderate light intensity, moderate water availability or moderate soil moisture and medium statured trees (5-20m). Hence, this community was selected as study system as it suits to address the question studying the variation of plant functional traits in a gradient of light and water.

Establishment of plots and environmental characterization: Potential sites for plots for each habitat as per habitat definition (tree cover) were marked from Google Earth images. These marked areas were inspected and plots were laid in areas which actually matched the habitat description (tree cover, light intensity etc). Marked points were not chosen if they are not accessible (steep slope etc) even if they matched the habitat description. Nine plots of 20m * 20m were established in each habitat. Girth at Breast Height (GBH) (cm) and Height (m) were measured for all woody plants (shrubs, lianas and trees) in the plots. Light intensity under the canopy was measured at the four corners and the centre of the plots for every plot in October-November. The under canopy light is represented as the relative light percent available under canopy with respect to light intensity measured on the same day in a fully open place (ie, zero canopy density) **.**Soil moisture content and soil water holding capacity was measured at three points (South-East corner (sub-plot A1), centre and North-West corner (sub-plot D4)) of every plot during October-November, December and April. Soil was collected up-to 15 cm and was brought to laboratory in Ziploc bags. The soil samples were processed (stones, roots, insects etc were removed) and fresh weight (g) was measured. The water saturated weight of soil samples was measured. The samples were oven dried at 60˚C for a week and the dry weight of the samples was taken. Tree cover was measured in all plots using densiometer in mid March, 2016 to estimate the lowest tree cover in the plots as March is the peak senescing month in the community as per earlier studies from the lab.

Sampling Design: All mature woody species (shrubs, lianas and trees) inside the plots were sampled for functional traits. All trees above 30cm GBH is considered as mature individuals as per available forest inventories. From the collected GBH values from the plot specific GBH cut offs were given for shrubs and lianas. Shrubs were further classified into small shrubs and long shrubs based on height and were assigned GBH cut offs as 5 and 10 respectively (Appendix 2).

Hence, GBH is used as a measure to determine whether the individual is established in the community. Most trees in Crest forest were profusely branched. Adding up GBH of all the branches as per available protocols seemed to misrepresent GBH (Appendix 3).

So, in order to avoid the problem, sum of the areas of the individual branches was calculated and was converted into corresponding GBH. For example, if an individual has two branches of with GBH 1 and GBH 2 with diameter d1 and d2 respectively. Total basal area of the plant is calculated ie, sum of the areas of both the branches is found. The diameter (D) and GBH is calculated from the total basal area. And the GBH cut off was applied to the calculated GBH.

Structure and composition of the three habitat types: One of the major goals of this study was to define the three habitats in terms of their structure and composition. The structure of the habitats was described on the basis of the mean GBH, mean height and density of the woody plants which are above the set GBH cut off.

Species – Area curve was plotted to ensure that study is not limited by the area of sampling (Appendix 5). The species composition was defined using relative abundance of the species, relative coverage or relative dominance of the species and different diversity indices such as Shannon's Index [$H= -\sum_i^n p_i \ln (p_i)$, where, p_i is the relative abundance of species i] (Shannon and Weiner, 1963), Equitability Index [E=H/log(S), where S is the total number of species in that site] (Black *et al*., 1950) and Simpson's Diversity Index [$S=\sum_i^n (p_i)^2$] (Simpson, 1949). Relative abundance is calculated as the number of individuals of a species to total number of individuals in a site. Relative coverage or relative dominance is calculated as the sum of basal area of the individuals of a species to the total basal area of individuals in a site. Rank – Abundance curve was plotted to understand the species richness and evenness of the three habitats.

The diversity indices were calculated for each habitat. All these indices were calculated for different life forms separately to understand the pattern of distribution of the different life forms in the habitats. The communities were compared to each other using Sorenson's Similarity coefficient [c/ (a+b−c)] (Sorenson, 1948)and Jaccard's Similarity Index [2c/ (a+b)] (a and b are the number of species in habitat one and two and c is the number of species which is present in both the habitats) (Jaccard, 1912). The species were assigned ranks according to relative abundance in the respective habitat and

Rank-abundance curve was plotted for all habitats to understand about the species evenness in the three habitats.

Measurement of Leaf Traits: Leaf samples were collected from mature individuals of all woody species from first five plots during October to November 2015. Five mature sun exposed leaves per individual were collected from each individual at the level of the top canopy. If the leaves are inaccessible at canopy level, mature sun exposed leaves are collected from the side branches. The leaves were brought to the laboratory in paper bags kept in moist Ziploc bags. Extra leaves were collected for nutrient analysis in the case of small leaves. To aid statistical analysis, leaves from collected from individuals near the plot for species which has less than five individuals inside the plot in a habitat.

Leaf traits were measured as per methods in Garnier *et a*., 2013. In the laboratory, the leaves were kept in Ziploc bags filled with sufficient water and were kept for saturation at 4˚C for 12 hours. After saturation, the leaves were cleaned with tissue paper and saturated fresh weight was measured. After scanning with Canon 600 LIDE at 300dpi for measuring the leaf area, leaves are kept at 60˚C for 72 hours for drying to get the leaf dry weight. The dry weight was noted after 72 hours of drying. Leaf area was calculated using ImageJ (Schneider *et al*., 2012). LDMC was calculated as the ratio between leaf dry weight (g) to leaf saturated weight (g) whereas LMA is the ratio of leaf dry weight (g) to leaf area (m^2).

Each species was assigned a habitat based on the relative density and relative dominance of the species. So, the species have species specific mean leaf traits. Similarly, the trait values of individuals in a habitat were averaged to get a habitat specific species mean trait values. Abundance weighted plot mean trait [Plot level mean trait value = $\sum_i^n p_i x_i$, p_i is the relative cover or relative density of the species i and x_i is the mean trait value of species i] was calculated for every trait for each plot as the summation of the mean trait value of the species weighted by its relative coverage and relative dominance. Community weighted mean of each trait was calculated for each habitat as the average of the plot values. Functional Diversity (FD) of each plot was calculated using Rao's Coefficient.

$$\text{Rao's coefficient} = \sum_i^n \sum_j^n p_i \, p_j * |(x_i - x_j)|$$

Where, x_i and x_j are mean trait values of species i and j and p_i and p_j are relative dominance of species i and j. FD of each trait was calculated for each habitat as the average of the plot values.

CWM was calculated using local mean (mean trait value of the species in the habitat) and using global mean (mean trait value of the species in the community).

$$CWM_{intra} = CWM_{local} - CWM_{global}.$$

Similarly, FD_{intra} was calculated as the difference between FD_{local} and FD_{global}.

Data Analysis: All the analysis was done using STATISTICA Version 10 (Team EAT). For under-canopy relative light intensity, soil moisture content and tree cover, one way Anova (Analysis of variance) was performed to check whether the habitats are different. Tukey post-hoc test was also done on under-canopy relative light intensity and soil moisture content. For the species which were present in more than one habitat, two way Anova was performed to understand the effect of species, habitat and their interaction on a) open and edge b) open and closed c) edge and closed . For CWM, one way Anova was done to understand the effect of habitat on CWM based on relative density as well as CWM based on relative coverage. For CWM values which showed significance, Tukey's post-hoc test was done. For FD, one way Anova was done to understand the effect of habitat on CWM based on relative coverage. For FD values which showed significance, Tukey's post-hoc test was done. For understanding the relative contribution of intra-specific variation and species turnover in the observed change in the CWM and FD across the different habitats, three parallel Anova's were done on the intra, local and global (species turnover) values.

$$SS_{local} = SS_{intra} + SS_{global} + \text{Covariance} + \text{Error}$$

Covariance is calculated as

$$\text{Covariance} = SS_{local} - (SS_{intra} + SS_{global})$$

The relative contribution of intra-specific variation and species turnover in the observed change in the CWM and FD across the different habitats was calculated using Sum of Square decomposition method (Leps *et al*., 2011, De Bello et al., 2011).

Results:

Habitat Description: The mean height, GBH and density (number of individuals per m^2) of plants increased from open to closed habitats (Table 1). Soil depth is very low in the open habitats, increases in the edge, and is highest in the closed habitats (Ghadage *et al.,* 2013).

Table 1: Girth at Breast Height (GBH) (cm), height (m), density (number of individuals per m^2, and soil depth (m) of the three habitats (open, edge and closed). Standard error (SE) of the traits is shown in the table.

Traits	**Open**	**Edge**	**Closed**
Mean GBH (cm)	32.35 ± 1.21	46.80 ± 1.62	68.36 ± 3.44
Mean height (m)	3.32 ± 0.07	9.22 ± 0.18	16.96 ± 0.72
Density (number/m^2)	0.109	0.133	0.148
Soil depth	~15 cm	intermediate	>100 cm

Tree cover in the open habitats was low, while for the edge and closed habitats the canopy is mostly completely closed ($F=247.99$, $p<0.001$) (Fig. 2-a). This difference in cover was reflected in the under canopy relative light intensity. Relative light intensity under canopy was highest for open and least for closed habitats ($F=66.06$, $p<.001$). While the relative light intensity was higher for the edge compared to the closed habitats, this was not significantly different. Light intensity in open and edge was very heterogeneous as compared to closed habitat (Fig 2-b). Soil moisture content (water availability) is lower for open habitats, but edge and closed were similar [$F=21.57$, $p<0.001$ for October and $F=8.46$, $p<0.05$ for December). Soil moisture content decreased from October to December in all the habitats (Fig 2-c).

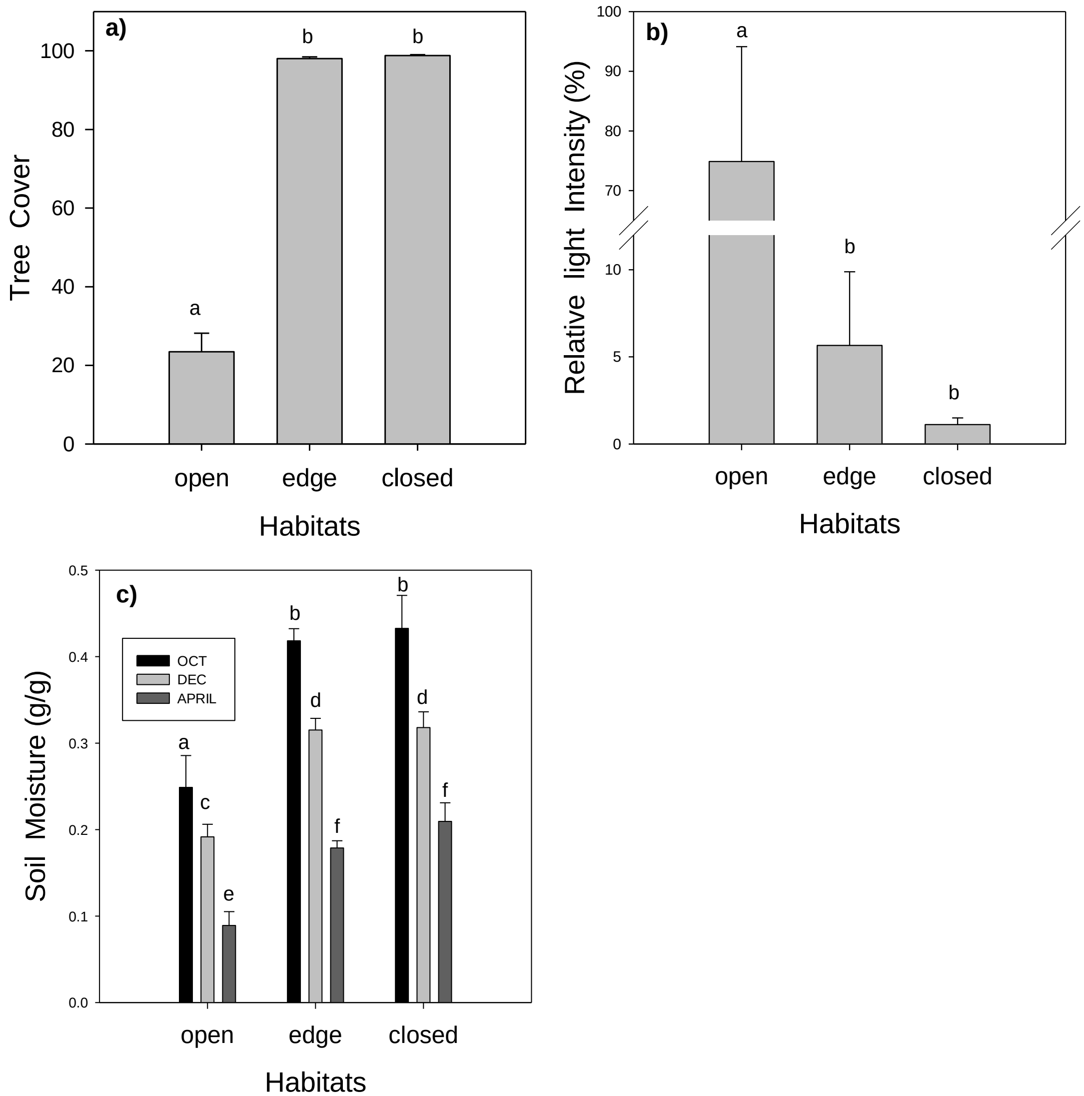
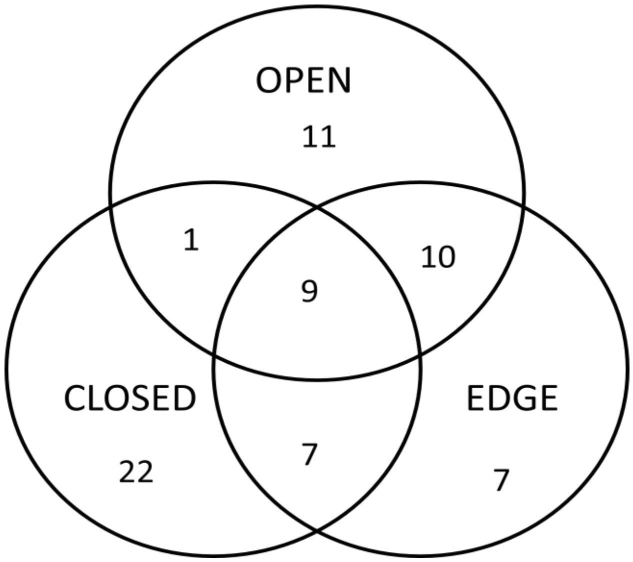


Fig 2: a) Tree cover density between the three different habitats measured using densiometer in March, b) Relative light intensity (%) measured at breast height in the different habitats; c) Soil moisture content (W/W) in the different habitats measured in October and December. Different letters correspond to habitats which were significantly different from each other at $p < 0.05$. Error bars represent ± one standard error.

There was a total of 78 woody species in this community. This comprised of 17 lianas, 11 shrubs and 43 tree species. The closed habitat had the highest number of unique species whereas edge had the least. There was a higher overlap of species between



the edge and open habitat, and the least overlap of species between open and closed (Fig. 3).

Fig 3: The number of species in each habitat type, with the numbers that overlap between the different habitats.

This can be seen in the decrease in similarity indices going from open and edge comparison to the edge to closed comparison. As expected, the open and closed habitats which are not contiguous which each other show the lowest similarity (Table 2).

Table 2: Summary of the similarity indices between the different habitat pairs (open and edge (OP – ED); edge and closed (ED – CL); and open and closed (OP – CL;) and across all the three habitats - open, edge and closed (OP – ED – CL).

Similarity indices	**OP-ED**	**ED-CL**	**OP-CL**	**OP-ED-CL**
Sorenson's Similarity Coefficient	0.59	0.44	0.26	0.26
Jaccard's Similarity Index	0.42	0.29	0.15	0.11

There is an increase in the species richness from open to edge to closed habitats. However, Shannon's indices were not very different between the three habitats but Shannon's index was higher for closed whereas open and closed had similar values. Evenness in the community was the lowest for the open habitat and similar for the edge and the closed (Table 3). This is also evident in the rank abundance curve for the three habitats (Appendix 6). The species richness of shrubs was similar across all habitats. The number of lianas was much greater in the closed forest while the number of trees was lower in the open forests.

Table 3: Summary of the species diversity indices for the three habitats examined (open, edge and closed): a) All life forms; b) Shrubs; c) Lianas; and, d) trees.

Diversity indices		Open	Edge	Closed
a) For all life forms	Species Richness	31	33	39
	Simpson's Index	0.18	0.19	0.47
	Shannon's Index	2.32	2.77	2.78
	Evenness Index	0.68	0.79	0.76
b) Shrubs	Species Richness	7	7	8
	Simpson's Index	0.076	0.018	0.008
	Shannon's Index	1.101	0.620	0.437
	Evenness Index	0.036	0.019	0.011
c) Lianas	Species Richness	4	5	12
	Simpson's Index	0.002	0.001	0.011
	Shannon's Index	0.282	0.253	0.724
	Evenness Index	0.009	0.008	0.019
d) trees	Species Richness	16	22	20
	Simpson's Index	0.075	0.076	0.077
	Shannon's Index	0.922	1.894	1.549
	Evenness Index	0.030	0.057	0.040

Memycelon umbellatum, Syzygium cumini, Mangifera indica, Olea dioica, Catunaregam Spinosa, Actinodaphne angustifolia, Dimorphocalyx lawianus, Xantolis tomentosa and Syzygium gardneri are the most dominant species in the community (Appendix 4) *Memycelon umbellatum*, *Catunaregam Spinosa* and *Lasiosiphon eriocepha*lus are the most dominant species in the open where as *Memycelon umbellatum*, *Xantolis tomentosa* and *Syzigium cumini* are the *Xantolis tomentosa* most dominant species in the edge habitat. *Mangifera indica, Memycelon umbellatum* and *Dimorphocalyx lawianus* are the species which are most dominant in the closed habitat. Though, *Pavetta indica* was one of the most abundant species in the open and edge it is not the one of the most dominant species in those habitats (Appendix 3).

Intra-specific variation: For all of the traits examined, species differed in the pair wise habitat comparisons (Table 4). However, we were not interested in species level differences in this analysis as we were only comparing the subset of species that overlapped in the pair wise habitat comparisons.

Table 4: Intra-specific variation in leaf traits. Summary of F statistics from a two way ANOVA examining variation in leaf traits in the different pairwise combination of habitats. Leaf Mass Area (LMA), leaf Dry Matter Content (LDMC) and Leaf Area (LA) for: a) Open and Edge, b) Edge and Closed and c) Open and Closed. The values which are significant at $p < 0.05$ are in bold.

		LMA	LDMC	LA
a) Open – Edge	Species	**101.907**	**112.61**	**68.111**
	Habitat	**146.121**	**91.63**	**33.382**
	Habitat*Species	**2.356**	1.28	**3.727**
b Edge – Closed	Species	**32.514**	**26.43**	**34.061**
	Habitat	**6.389**	0.35	3.786
	Habitat*Species	1.102	1.72	0.38
c) Open – Closed	Species	**120.258**	**22.49**	**22.985**
	Habitat	**56.645**	**20.14**	**29.9807**
	Habitat*Species	**7.81**	**3.134**	0.5779

Importantly, there was a significant effect of habitat indicating significant intra-specific variation. There was significant intra-specific variation for all of the traits in the open and edge, and open and closed comparisons. In the comparison between edge and closed intra-specific variation was only significant for LMA. For some of the comparisons, there was significant specie * habitat interactions indicating that the change in traits across habitats was not consistent for the different species. However, even when significant this interaction explained a small percentage of variation.

LMA decreased from open to edge to closed habitats. This direction of change was similar across all the species however the magnitude of change was not the same for the different species (Fig. 4) (Appendix 7).

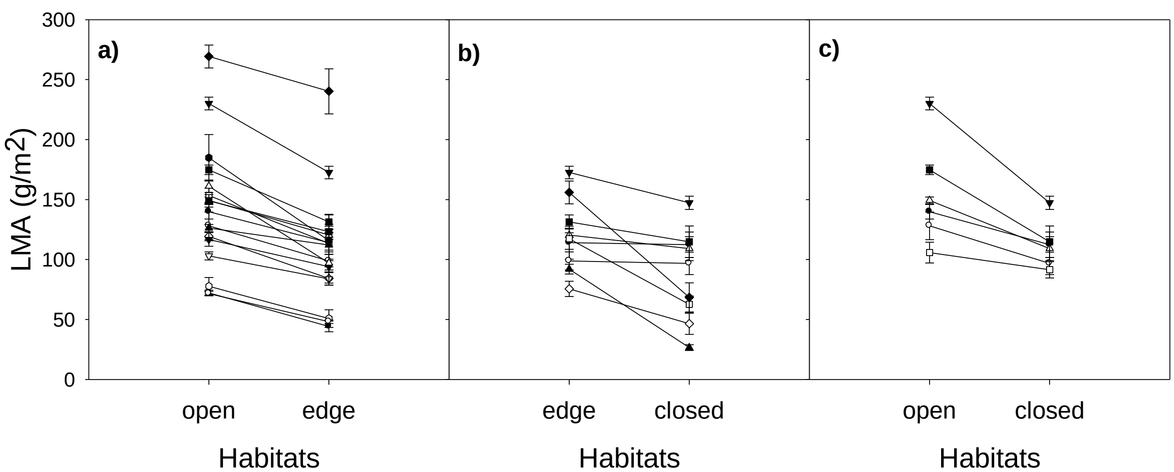


Fig 4: Intra-specific variation in Leaf Mass per Area (LMA) in species that were common to: a) open and edge (OP – ED); b) edge and closed (ED – CL); and c) open and closed (OP – CL) habitats. Error bars represent ± one standard error.

LDMC decreased from open to edge and open to closed but was not different for the comparison between the edge and the closed. The direction and magnitude of change in LDMC was consistent across species (Fig. 5) (Appendix 8). LA increased from open to the edge and open to closed habitats. There was no change in LA between the edge and the closed habitat. In the open to the closed comparison, the change in LA was consistent across species, whereas in the open to the edge comparison, the change in leaf area was different for the different species (Fig. 6) (Appendix 9).

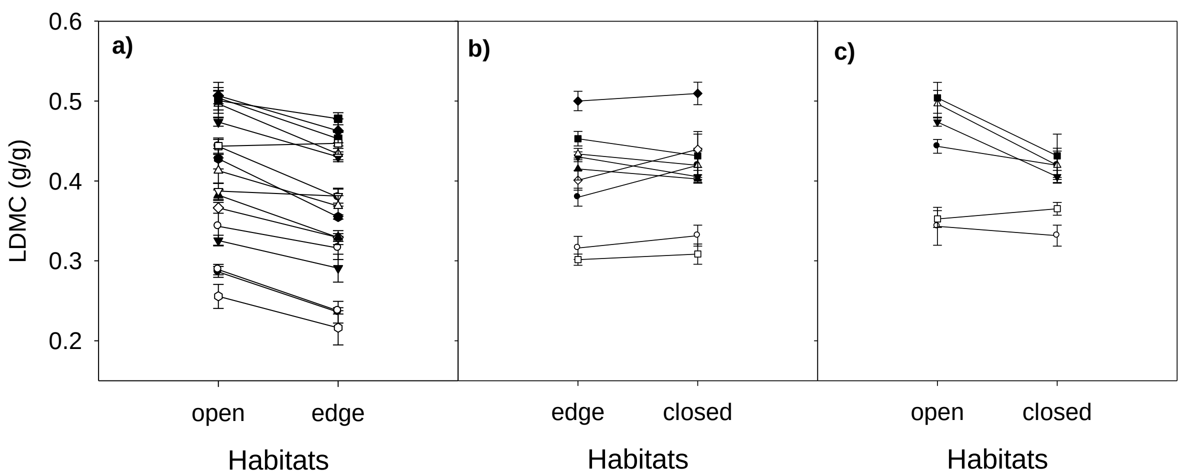


Fig 5: Intra-specific variation in Leaf Dry Matter Content (LDMC) in species that were common to: a) open and edge (OP – ED); b) edge and closed (ED – CL); and c) open and closed (OP – CL) habitats. Error bars represent ± one standard error.

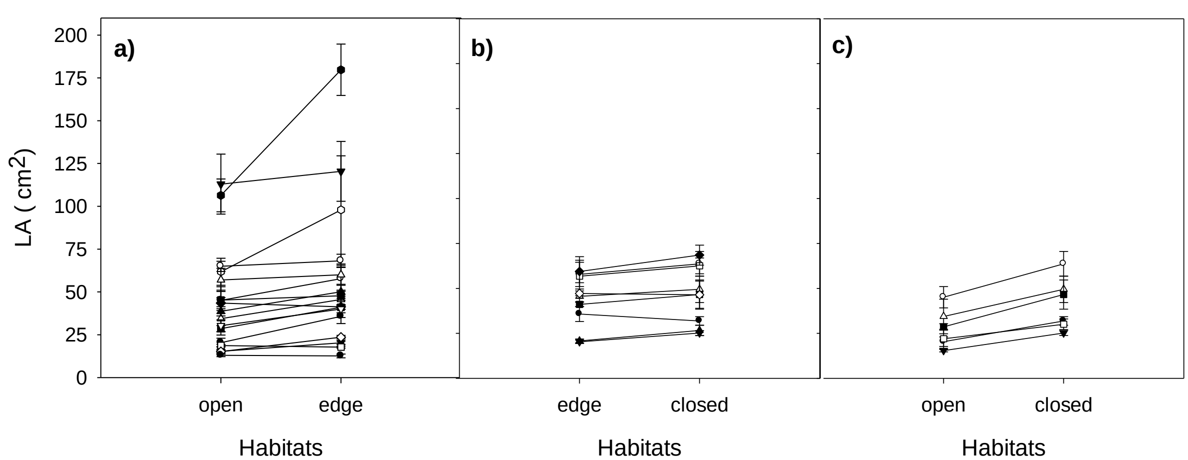


Fig 6: Intra-specific variation in Leaf Area (LA) in species that were common to: a) open and edge (OP – ED); b) edge and closed (ED – CL); and c) open and closed (OP – CL) habitats. Error bars represent ± one standard error.

Community Weighted Mean (CWM): The overall patterns of change across the three habitats in the CWM values estimated using relative dominance and relative density were similar.

Table 5: Variation between the habitats in Community Weighted Mean (CWM) trait values. CWM was calculated based on a) Relative Density; and b) Relative Cover for Leaf Mass per Area (LMA), Leaf Dry Matter Content (LDMC) and Leaf Area (LA). F-statistics from one-way analysis of variance are presented. The values which are significant at $p < 0.05$ are in bold.

	LMA	**LDMC**	**LA**
a) CWM (Density based)	2.86	1.12	1.67
b) CWM (Cover based)	**4.62**	0.16	**9.87**

For CWM using relative dominance, LMA decreased from open to edge, but did not change from edge to closed. For LDMC, we could not detect any significant differences. For LA, there was an increase in CWM from open to edge, but no difference between edge and closed (Appendix 11).

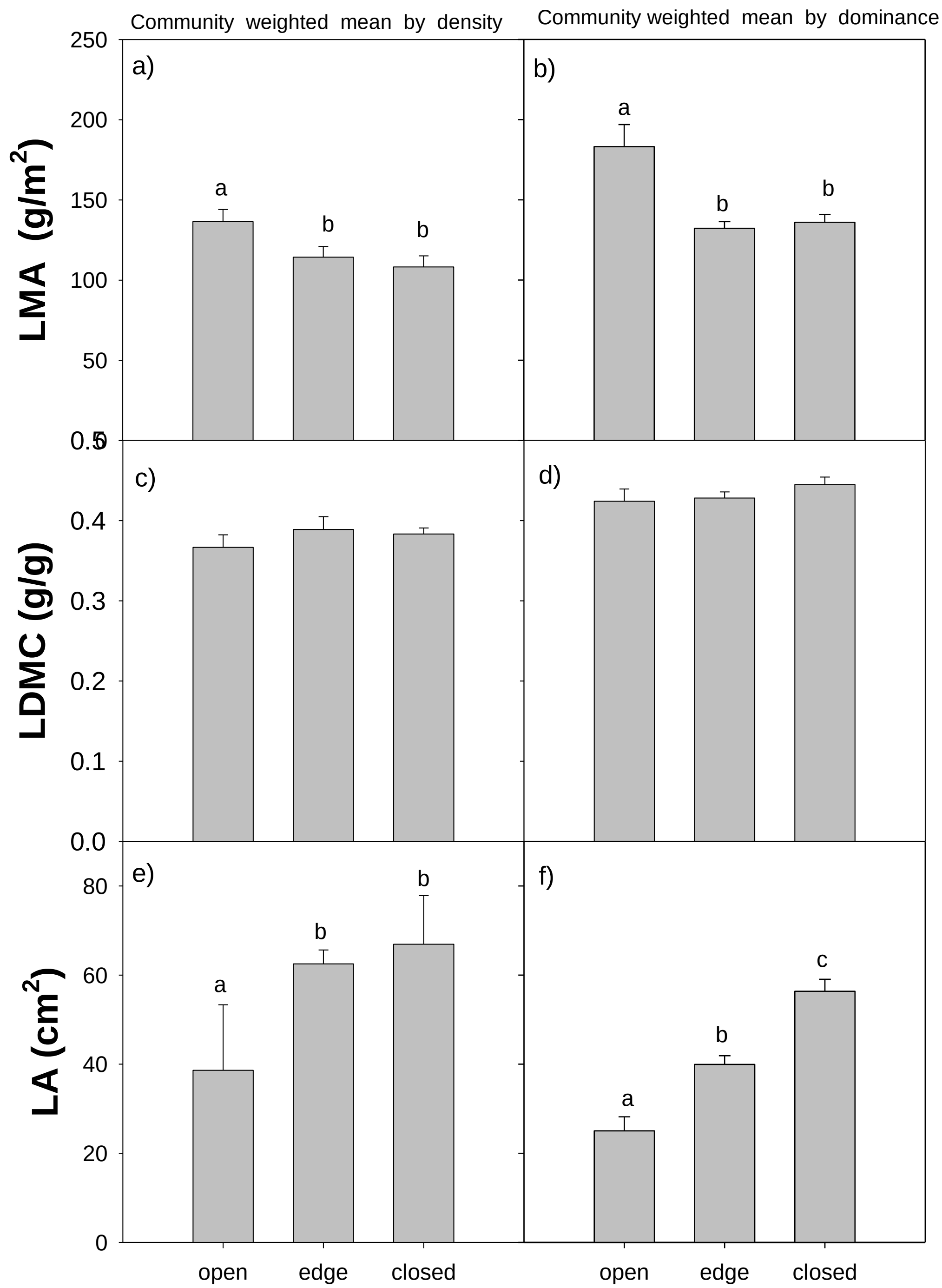


Fig 7: Community Weighted Mean trait (CWM) values for Leaf Mass per Area (LMA), Leaf Dry Matter Content (LDMC) and Leaf Area (LA). CWM values were weighted by relative density for a), c) and e), and by relative cover (dominance) for b), d) and f). Unique letters depict significant differences at $p < 0.05$ (Tukey's post-hoc test). Lack of

letters in panels imply no statistically significant differences. Error bars represent ± one standard error.

Functional Diversity: LMA decreased from open to edge, but did not change from edge to closed. For LDMC, we could not detect any significant differences. For LA, there was an increase in CWM from open to edge, but no difference between edge and closed

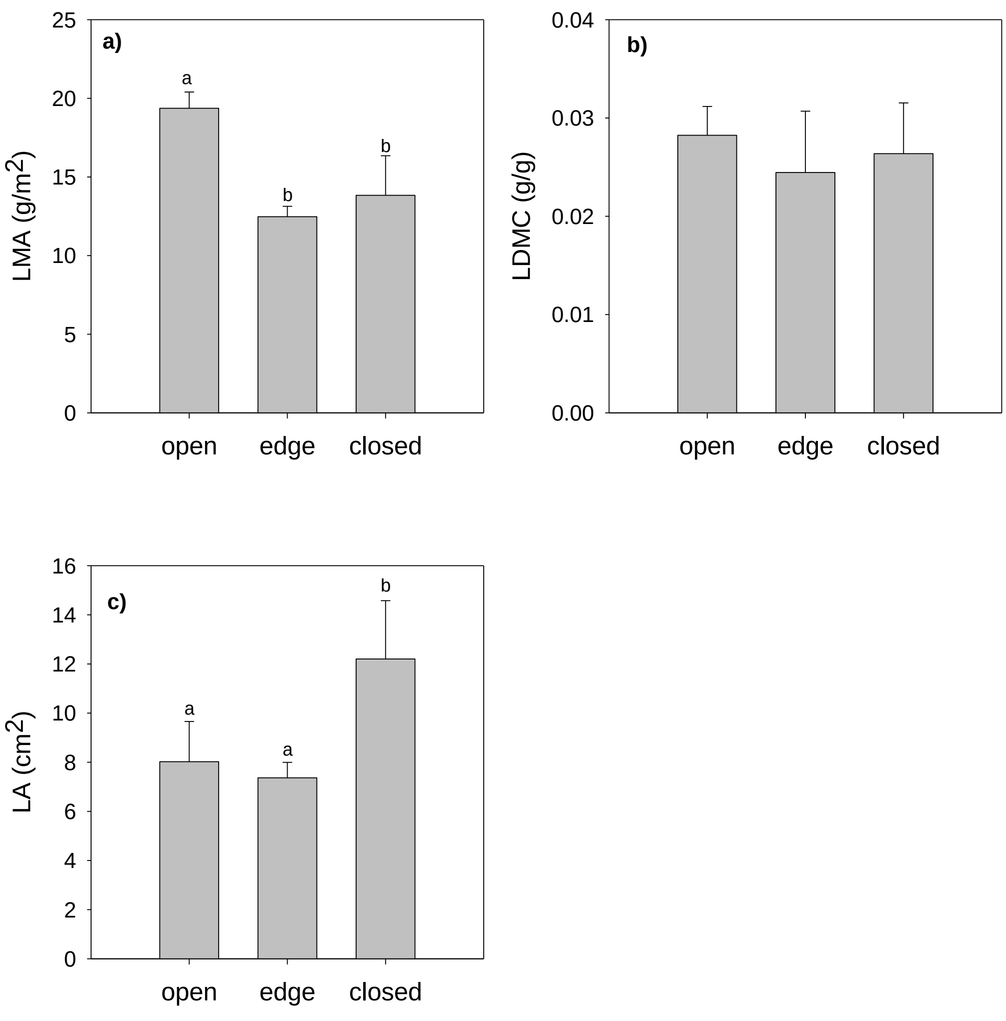


Fig 8: Functional Diversity (FD) values for Leaf Mass per Area (LMA), Leaf Dry Matter Content (LDMC) and Leaf Area (LA). Unique letters depict significant differences at $p < 0.05$ (Tukey's post-hoc test). Lack of letters in panels imply no statistically significant differences. Error bars represent ± one standard error.

Partitioning of Variance: The relative contribution of intra-specific variation to inter-specific variation in the observed variation of community weighted mean and functional diversity weighted by relative dominance shows that there is significant contribution of intra-specific variation.

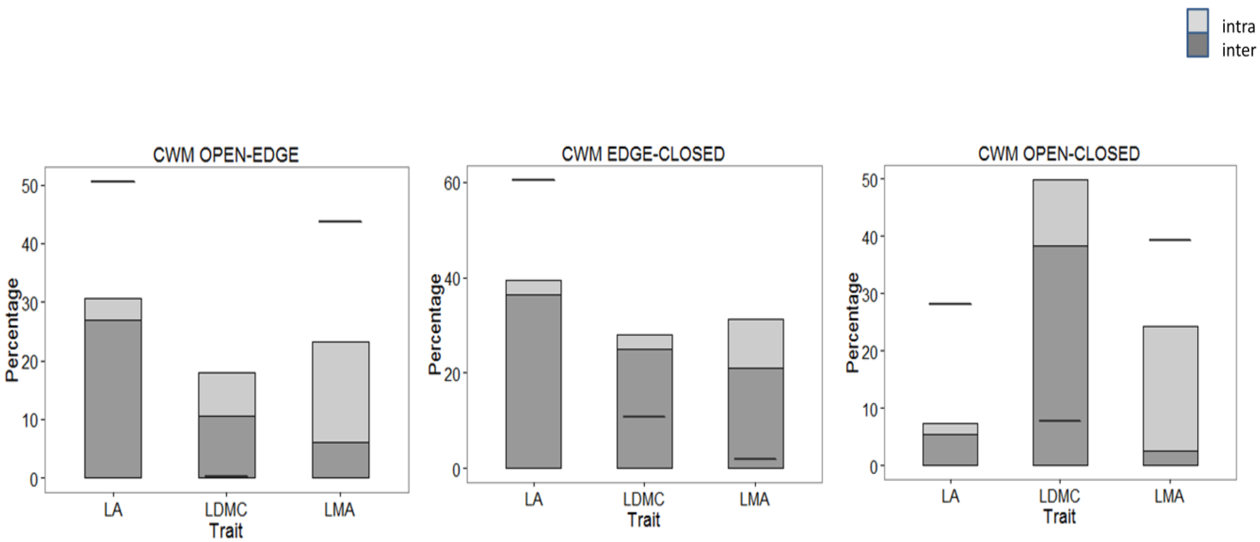


Fig 9: Partitioning of variance of Community Weighted Mean of leaf functional traits (Leaf Mass per Area (LMA), Leaf Dry Matter Content (LDMC) and Leaf Area (LA)) into intra-specific and inter-specific variation across habitat pairs. The black line shows co-variation between inter-specific and intra-specific variation. If the co-variation is cutting the bar graph, inter-specific and intra-specific variations are in opposite direction and in the same direction if it is above the bar graph

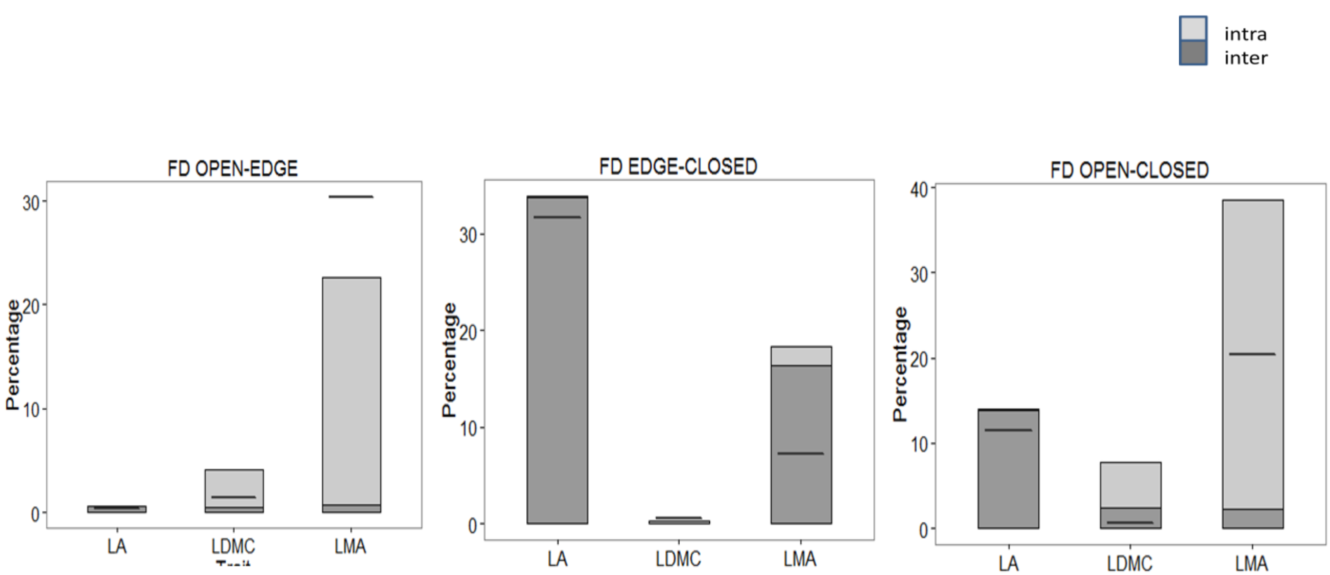


Fig 10: Partitioning of variance Functional Diversity of leaf functional traits (Leaf Mass per Area (LMA), Leaf Dry Matter Content (LDMC) and Leaf Area (LA)) into intra-specific and inter-specific variation across habitat pairs. The black line shows co-variation between inter-specific and intra-specific variation. If the co-variation is cutting the bar graph, inter-specific and intra-specific variations are in opposite direction and in the same direction if it is above the bar graph

Relative contribution of intra-specific variation to species turnover was less for CWM of LA. Relative contribution of intra-specific variation to species turnover was higher for CWM of LDMC and LMA for open to edge habitat as compared to edge to closed habitat. The relative contribution of the intra-specific to species turnover was higher for FD of LMA and LDMC in open to edge habitats where as comparatively very less in edge to closed habitat. FD of LA was highly explained by Species turnover. The contribution of inter-specific variation was very less for FD of LA.

Discussion

This study tried to understand the variation of plant functional traits of woody plant species across three contrasting habitats in the gradient of light and water in a seasonally dry tropical forest in the northern Western Ghats. The three habitats are considerably different in tree cover density, under canopy relative light density and soil moisture content. Species composition and structure of the habitats are different. The leaf functional traits of the species are significantly different. For the species which were present in more than one habitat, there was considerable intra-specific variation in the traits examined. CWMs of LA and LMA weighted by relative dominance varied significantly across the three habitats.

Habitat Description: Density of plants and tree cover in the habitats indicate that the under canopy light condition for open and close is low and high respectively. The light measurements in the habitats are in consistence with this inference. The height of the plant is a proxy for the water availability and soil depth. The soil moisture content at October (after rainfall) and December (starting of dry season) showed that the water availability goes down in the habitats after the rainfall. The difference in the relative dominance and relative density is mainly due to the difference in the life form. The species may be abundant but they may be occupying only a small basal area. For example, Pavetta indica is one of the most abundant species in open and edge habitat. But being a shrub, the total basal area occupied by the species is less in both the habitat which is reflected in its relative dominance value. Similarity indices and diversity indices showed that habitats were less similar from each other though light and water availability measurements showed similarity between edge and closed habitats.

Intra-specific variation: The studied functional traits varied across the habitat for the species which are present in more than one habitat. The variation in functional traits of the species across habitats indicates the effect of the environmental gradient on the functional traits. Poorter *et al.* reported that the low water availability drives the individual to closely pack the cells with higher density. Thus, low water availability leads to species with high LMA and LDMC leaves like in the case of open habitats. For variation in LMA and LA, there is a significant effect of the habitat and species. The effect of the interaction between habitat and species is very less as compared to the effect by habitat and species independently. LA decreases as it goes from close to open as hypothesized to optimize the loss of water due to transpiration as the water availability in the open habitat is low (Westoby, 2002; Wright *et al.*, 2004; Wright *et al.* 2005). Similarly, the low light availability in the closed habitat drives the species to high LA to increase the area of light interception (Westoby, 2002). LA and LMA of most of the species varied consistently across open and edge and open and closed but the species trends were not consistent between edge and closed habitats

Community weighted mean and functional diversity: For CWM weighted by coverage, CWM of LA and LMA of open habitat is different from edge and closed habitat but, CWM of LA and LMA of edge habitat is not different from closed habitat. Though, community similarity indices showed less similarity between the habitats, the examined traits at the level of the community shows that the open is different from edge and closed but, edge and closed are not different. Rao’s coefficient is derived from Simpson’s index. But they showed contrasting results in the study. Simpson’s index indicated lower diversity in open habitat but, Rao’s coefficient showed higher diversity in the case of LMA. The functional trait value at the level of the community reflects the environmental gradient. Hence, functional traits are a better indicative of effect of environmental gradients on communities. Moreover trait based approach is quantitative giving an option to actually compare between two communities.

The community level values help to draw information about the community. For example, two communities with a low and high LMA value tell that the community with high LMA value is a slow growing community as compared to community with a low LMA value. Knowledge about the species composition and functional traits in different environmental gradient help us to predict the response of the communities to climate changes.

Relative role of intra-specific variation and species turnover: There was a significant contribution of intra-specific variation showed significant contribution to both CWM and FD across different habitats. Results are in terms with the results from other studies showing intra-specific variation explaining more variation in traits like SLA (surface area to leaf mass) and LDMC whereas lower for traits like leaf area (Siefart *et al.*, 2015). Carmona *et al*., 2016 states that FD is more sensitive to inclusion of intra-specific variation into calculation. The general understanding from previous studies is that intra-specific variation decreases as the geographical gradient increases. But, most of these studies look at a bigger geographical gradient than this study. This study focuses on the shift in the community responses at a smaller geographical gradient, ie, across different habitat types in a community. We observe sharp changes in the contribution of intra-specific variation to species turn over for FD of LMA across the different habitats. Hence, the relative contribution of intra-specific variation and species turnover varies within a community. This points to the need of understanding within community changes at the equal importance as that of across community shifts in response to different environmental gradients. Recent studies has pointed that there is a significant contribution of intra-specific variation for the variation within communities (Siefert *et al*., 2015)

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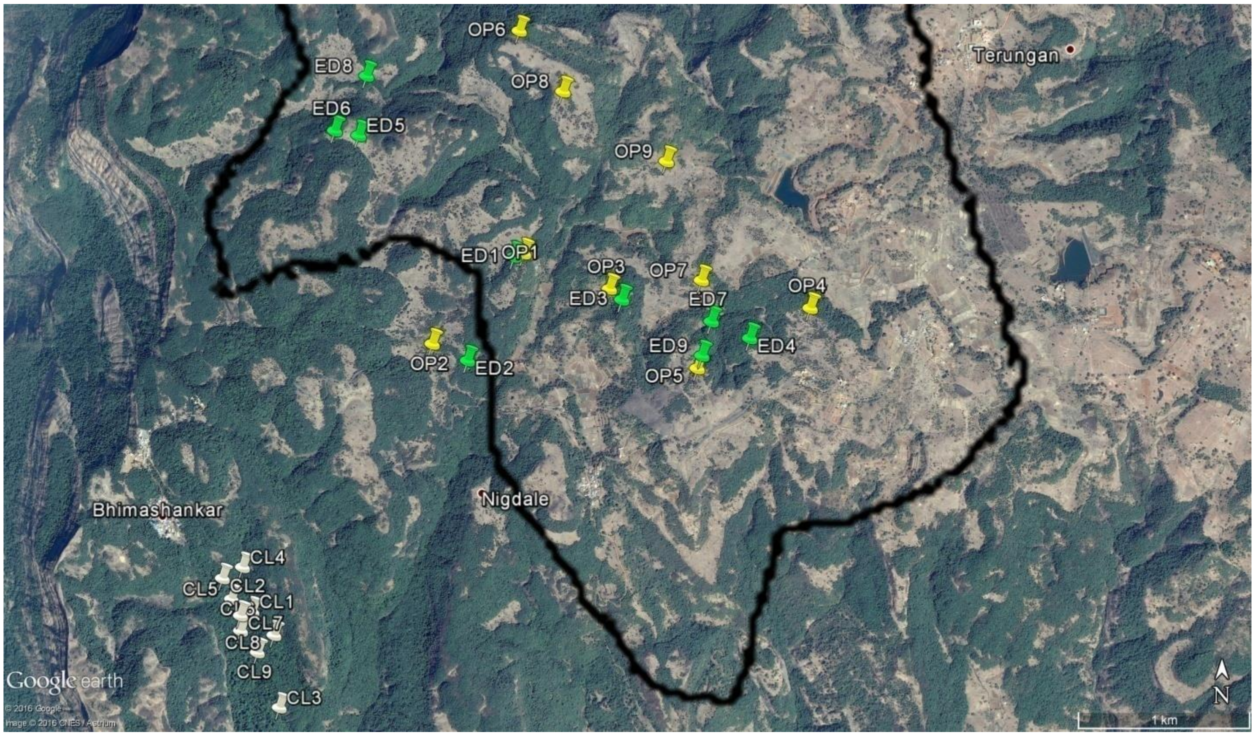
Appendix



Appendix 1: Google Earth image showing the position of the plots in Bhimashankar Wildlife Sanctuary. The plots are labeled as yellow for open (OP), green for edge (ED) and white for closed (CL).

Appendix 2**:** Table giving description of the species in the study in terms of name of the family, local name, plant type (trees-T; Shrubs-S; Lianas- L) and habitat in which they are dominantly present

SPECIES NAME	SPECIES CODE	FAMILY	LOCAL NAME	PLANT TYPE	HABITAT
Actinodaphne angustifolia	AC	Lauraceae	Malwa	T	Edge
Amoora lawii	AL	Meliaceae	Pandhra Telya	T	Closed
Embelia sp1	AM	Vitaceae	Ambetivel	L	Open
Atlantia racemosa	AR	Rutaceae	Chinger	T	Edge
Caesaria sp.	BO	Vivianiaceae	Bogada	S	Open
Bridelia retusa	BR	Phyllanthaceae	Ashind	T	Edge
Gymnosporia rothiana	BV	Celastraceae	Balvand	S	Open
Careya areborea	CA	Lecythidaceae	Kumbhayi	T	Open
Carissa carandas	CC	Apocyanaceae	Karvandi	S	Open
Canthium diococcum	CD	Rubiaceae	Kandkudal	T	Open
Cassine glauca	CG	Celastraceae	Luir	T	Closed
Macaranga peltata	CH	Euphorbiaceae	Chandiya	T	Open
Cinnamomum malabaricum	CM	Lauraceae	Tamalpatra	T	closed
Colebrookea oppositifolia	CO	Lamiaceae	Dasai	S	open
Murraya koenigii	CP	Rutaceae	Curry patta	T	closed
Catunaregam Spinosa	CS	Rubiaceae	Rhandia	T	open
Callicarpa tomentosa	CT	Verbenaceae	Patgira	T	edge
Dysoxylum binectariferum	DB1	Meliaceae	Varna1	T	edge
Dysoxylum binectariferum	DB2	Meliaceae	Varna2	T	closed
Grewia tiliaefolia	DH	Teliaceae	Dhaman	T	
Dimorphocalyx lawianus	DL	Euphorbiaceae	Rai	T	closed
Diospyros montana	DM	Ebenaceae	Maskudal	T	edge
Diospyros sylvatica	DS	Ebenaceae	Kala Telya	T	closed
Elaeagnus conferta	EC	Eleaegnaceae	Ambeli	L	open
Embelia ribes	ER	Myrsinaceae	Ambati	L	edge
Flacourtia indica	FI	Salicaceae	Tambat	T	edge
Ficus racemosa	FR	Moraceae	Umbar	T	edge
Glochidion hohenackeri	GH	Euphorbiaceae	Bhoma	S	edge
Smilax ovalifolia	GT	Smilacaceae	Gotveli	L	open
Gnetum ula	GU	Gnetaceae	kombalvel	L	closed
Ancistrocladus heyneanus	HA	Ancistrocladaceae	Hardal	L	closed
Heterophragma quadriloculare	HF	Bignoniaceae	varas	T	open
Jasminum malabaricum	JM	Oleaceae	Kusar	L	Open
Lasiosiphon eriocephalus	LE	Thymelaeaceae	Rameta	S	Open
Leea indica	LI	Vitaceae	Andhphod	S	Edge

Litsea stocksii	LS	Lauraceae	Powti	T	Closed
Lepisanthes tetraphylla	LT	Sapindaceae	Ambakarap	T	Closed
Caeselpinia cucullatum	MC	Caesalpiniaceae	Gharnighi	L	Closed
Mangifera indica	MI	Anacardiaceae	Amba	T	Closed
Mallotus phillipensis	MP	Euphorbiaceae	Shendri	T	Edge
Memycelon umbellatum	MU	Melastomataceae	Karab	T	Open
Diploclisia macrocarpa	NA	Menispermiaceae	Naloti	L	Edge
Olea dioica	OD	Oleaceae	Karambu	T	Edge
Premna coriacea	PC	Verbenaceae	Chambhari	L	Closed
Garcinia talbotii	PH	Clusiaceae	Phansada	T	Closed
Pavetta indica	PI	Rubiaceae	Asavla	S	Open
Piper sp.	PP	Piperaceae	Nagvel	L	Closed
Psychotria sp.	PS	Rubiaceae	Psychotria	S	Closed
Rourea santaloides	RS	Connaraceae	Kalivel	L	Closed
Terminalia tomentosa	SA	Combretaceae	Sadada	T	Edge
Symplocos beddomei	SB	Symplocaceae	Lothadi	T	Edge
Syzygium cumini	SC	Myrtaceae	Jambhal	T	Edge
Syzygium gardneri	SG	Myrtaceae	Parjambhal	T	Closed
Terminalia bellerica	TB	Combretaceae	Behda	T	Open
Terminalia chebula	TC	Combretaceae	Hirda	T	Edge
Ziziphus sp.	TH	Rhamnaceae	Thoran	L	Edge
Allophyllus cobbe	TP	Sapindaceae	Tipna	L	Edge
Ventilago bombaiensis	VB	Rhamnaceae	Madvel	L	Closed
Meyna spinosa	VS	Rubiaceae	Aoul	T	Edge
Xantolis tomentosa	XT	Sapotaceae	Kombal	T	Edge
Unknown5	VI	Celastraceae	Vikhar	T	Closed
Unknown1	MD1		Jaiphal2	T	Closed
Unknown2	PA		Paba	T	Closed
Unknown3	PY		Pandriyeli	L	Closed
Unknown4	TA		Tambdatelya	S	Closed
Unknown6	DL2				Closed
Unknown7	LZ?				Closed
Unknown8	PG				Closed
Unknown9	PY2				Open
Unknown10	SD				Closed
Unknown11	TA2				Closed
Unknown12	UI				Closed
Unknown13	U2				Closed
Unknown14	U3				Closed
Unknown15	U4				Open
Unknown16	U5				Closed
Unknown17	WAM				Edge

Appendix 3: Relative Density of different species in the three habitats.

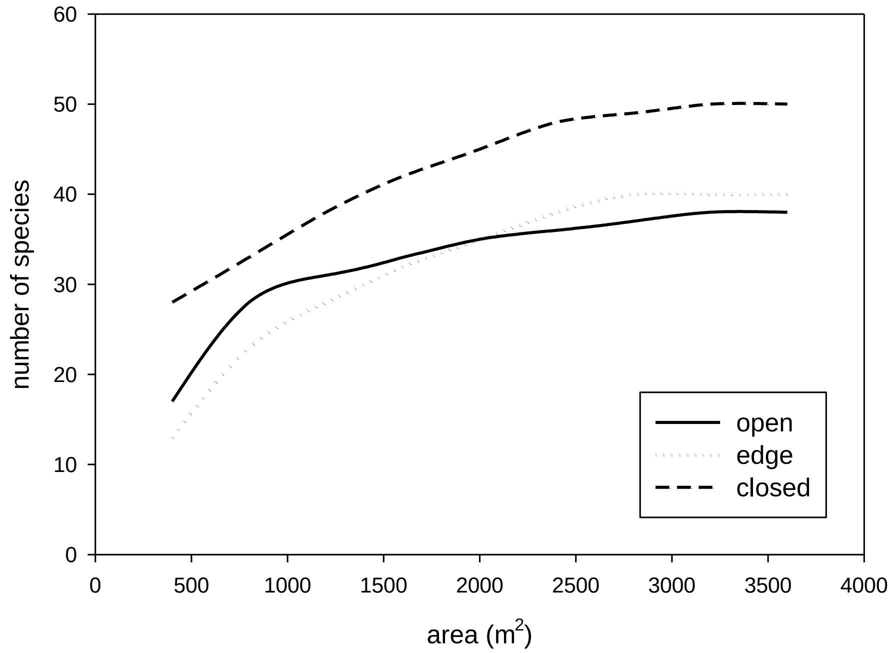
SPECIES	OPEN	EDGE	COSED	TOTAL
Actinodaphne angustifolia	0.004	0.053	0.003	0.060
Allophyllus cobbe	0.002	0.029		0.031
Amoora lawii		0.002	0.010	0.012
Ancistrocladus heyneanus			0.081	0.081
Atlantia racemosa	0.002	0.004	0.008	0.014
Bridelia retusa		0.017		0.017
Caesaria sp.	0.017			0.017
Caeselpinia cucullatum			0.023	0.023
Callicarpa tomentosa		0.006		0.006
Canthium diococcum	0.017			0.017
Careya areborea	0.002			0.002
Carissa carandas	0.054			0.054
Cassine glauca			0.005	0.005
Catunaregam Spinosa	0.090	0.025		0.115
Colebrookea oppositifolia	0.118		0.005	0.123
Dimorphocalyx lawianus			0.211	0.211
Diospyros Montana	0.006	0.023		0.029
Diospyros sylvatica			0.008	0.008
Diploclisia macrocarpa		0.023	0.005	0.028
Dysoxylum binectariferum		0.002		0.002
Dysoxylum binectariferum			0.008	0.008
Elaeagnus conferta	0.002			0.002
Embelia ribes		0.021	0.005	0.026
Embelia sp1	0.017	0.006	0.005	0.028
Ficus racemosa		0.004		0.004
Flacourtia indica	0.002	0.011		0.013
Garcinia indica	0.013			0.013
Garcinia talbotii			0.015	0.015
Glochidion hohenackeri	0.006	0.017		0.023
Gnetum ula			0.008	0.008
Gymnosporia rothiana	0.013	0.013	0.008	0.034
Heterophragma quadriloculare	0.039			0.039
Jasminum malabaricum		0.002		0.002
Lasiosiphon eriocephalus	0.111	0.008		0.119
Leea indica		0.020	0.002	0.022
Lepisanthes tetraphylla			0.018	0.018
Litsea stocksii			0.021	0.021
Macaranga peltata	0.002			0.002
Mallotus phillipensis	0.002	0.061		0.063
Mangifera indica		0.006	0.075	0.081

Memycelon umbellatum	0.235	0.212	0.154	0.601
Meyna spinosa	0.000	0.006	0.000	0.006
Olea dioica	0.002	0.057	0.028	0.087
Pavetta indica	0.216	0.126		0.342
Premna coriacea			0.008	0.008
Rourea santaloides			0.008	0.008
Symplocos beddomei		0.006		0.006
Syzygium cumini	0.002	0.080	0.023	0.105
Syzygium gardneri			0.013	0.013
Terminalia bellerica	0.002			0.002
Terminalia chebula	0.008	0.032	0.003	0.043
Terminalia tomentosa	0.009	0.002		0.011
Unknown 8	0.000	0.000	0.003	0.002
Unknown 9	0.002			0.003
Unknown 10	0.000	0.000	0.003	0.008
Unknown 11	0.000	0.000	0.008	0.003
Unknown 12	0.000	0.000	0.003	0.002
Unknown 16	0.000	0.000	0.000	0.002
Unknown 13	0.000	0.002	0.000	0.005
Unknown 2		0.002	0.003	0.049
Unknown 3			0.049	0.049
Unknown 4			0.087	0.087
Unknown 6			0.026	0.026
Unknown 7			0.003	0.003
Unknown1			0.003	0.003
Ventilago bombaiensis	0.000	0.000	0.033	0.033
Xantolis tomentosa	0.006	0.111	0.003	0.120
Ziziphus sp.		0.008	0.003	0.011

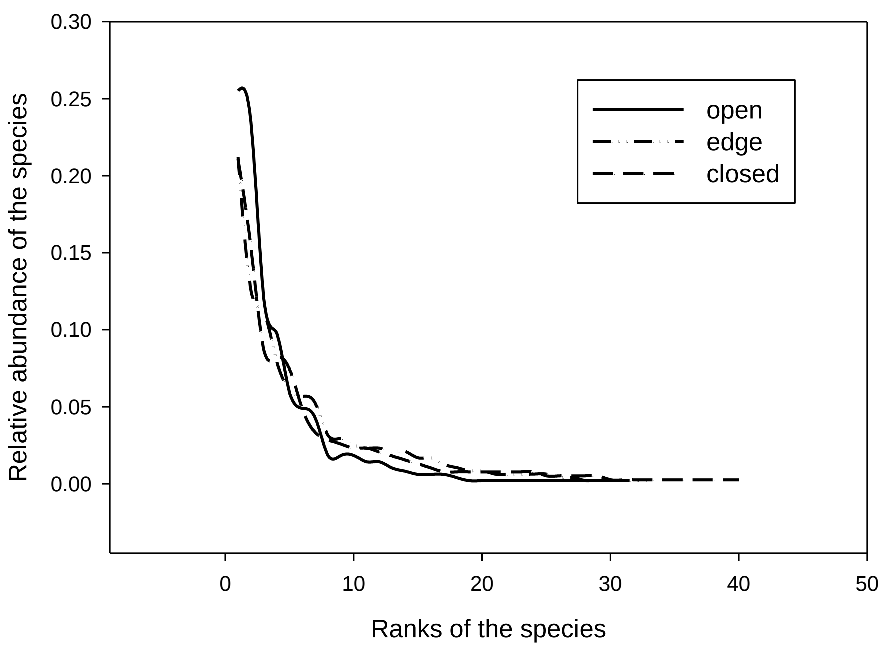
Appendix 4: Relative dominance (cover) of different species in the three habitats

SPECIES	OPEN	EDGE	CLOSED	TOTAL
Actinodaphne angustifolia	0.008	0.098	0.002	0.108
Allophyllus cobbe		0.001		0.001
Amoora lawii		0.001	0.016	0.017
Ancistrocladus heyneanus	0.0000	0.0000	0.0045	0.005
Atlantia racemosa	0.0004	0.0308	0.0084	0.040
Bridelia retusa	0.0000	0.0044	0.0000	0.004
Caesaria sp.	0.0003	0.0000	0.0000	0.000
Caeselpinia cucullatum	0.0000	0.0000	0.0012	0.001
Callicarpa tomentosa	0.0000	0.0016	0.0000	0.002
Canthium diococcum	0.0072	0.0000	0.0000	0.007
Careya areborea	0.0033	0.0000	0.0000	0.003
Carissa carandas	0.006			0.006
Cassine glauca	0.0000	0.0000	0.0007	0.001
Catunaregam Spinosa	0.178	0.005		0.183
Colebrookea oppositifolia	0.0017	0.0000	0.0000	0.002
Dimorphocalyx lawianus			0.105	0.105
Diospyros Montana	0.003	0.027		0.030
Diospyros sylvatica			0.005	0.005
Diploclisia macrocarpa		0.003	0.001	0.004
Dysoxylum binectariferum			0.008	0.008
Elaeagnus conferta	0.0003	0.0000	0.0000	0.000
Embelia ribes	0.0000	0.0027	0.0002	0.003
Embelia sp1	0.0012	0.0007	0.0006	0.002
Ficus racemosa	0.0000	0.0255	0.0000	0.026
Flacourtia indica	0.0007	0.0024	0.0000	0.003
Garcinia talbotii	0.0000	0.0000	0.0178	0.018
Glochidion hohenackeri	0.0007	0.0016	0.0000	0.002
Gnetum ula	0.0000	0.0000	0.0040	0.004
Grewia tiliaefolia				0.000
Gymnosporia rothiana	0.0022	0.0016	0.0003	0.004
Jasminum malabaricum	0.0147	0.0000	0.0000	0.015
Lasiosiphon eriocephalus	0.025	0.001		0.026
Leea indica		0.001		0.001
Lepisanthes tetraphylla			0.009	0.009
Litsea stocksii			0.018	0.018
Macaranga peltata	0.002			0.002
Mallotus phillipensis	0.001	0.018		0.019
Mangifera indica		0.014	0.344	0.358
Memycelon umbellatum	0.688	0.278	0.195	1.161
Meyna spinosa	0.0000	0.0049	0.0000	0.005

Olea dioica	0.0004	0.1182	0.0657	0.184
Pavetta indica	0.0124	0.0015	0.0000	0.014
Premna coriacea			0.012	0.012
Rourea santaloides			0.002	0.002
Smilax ovalifolia	0.0006	0.0000	0.0000	0.001
Symplocos beddomei	0.0000	0.0024	0.0000	0.002
Syzygium cumini	0.004	0.27	0.103	0.377
Syzygium gardneri	0.0000	0.0000	0.0416	0.042
Terminalia bellerica	0.0005	0.0000	0.0000	0.000
Terminalia chebula	0.0014	0.0173	0.0024	0.021
Terminalia tomentosa	0.02	0.007		0.027
Unknown 10	0.0001	0.0000	0.0000	0.000
Unknown 11	0.0000	0.0000	0.0001	0.000
Unknown 13	0.0000	0.0000	0.0004	0.000
Unknown 17	0.0000	0.0009	0.0000	0.001
Unknown 2	0.0000	0.0006	0.0004	0.001
Unknown 3	0.0000	0.0000	0.0111	0.011
Unknown 4	0.0000	0.0000	0.0007	0.001
Unknown 6	0.0000	0.0000	0.0034	0.003
Unknown 7	0.0000	0.0000	0.0018	0.002
Unknown1	0.0000	0.0000	0.0023	0.002
Ventilago bombaiensis			0.003	0.003
Xantolis tomentosa	0.002	0.059	0.009	0.070
Ziziphus sp.	0.0000	0.0002	0.0000	0.000



Appendix 5: Graph showing the species area curve for the three habitats (open, edge and closed). The number of plots is used as a proxy for area.



Appendix 6: Rank –abundance curves for species in the habitats (open. edge and closed).

Appendix 7: ANOVA tables for Leaf Mass per Area (LMA) across different habitat pairs a) open and edge (OP – ED) b) edge and closed (ED – CL) c) open and closed (OP – CL)

	SS	Degree of Freedom	MS	F	P
a) OP-ED					
Intercept	**3298832.00**	**1**	**3298832.00**	**7855.83**	**0.00**
Site	**61359.00**	**1**	**61359.00**	**146.12**	**0.00**
Species	**684688.00**	**16**	**42793.00**	**101.91**	**0.00**
site*species	**15826.00**	**16**	**989.00**	**2.36**	**0.00**
Error	106660.00	254	420.00		
b) ED-CL					
Intercept	**1595843.00**	**1**	**1595843.00**	**2638.47**	**0.00**
Site	**3865.00**	**1**	**3865.00**	**6.39**	**0.01**
Species	**157326.00**	**8**	**19666.00**	**32.51**	**0.00**
site*species	5332.00	8	666.00	1.10	0.37
Error	87701.00	145	605.00		
c) OP-CL					
Intercept	**982954.70**	**1**	**982954.70**	**1904.95**	**0.00**
Site	**29228.90**	**1**	**29228.90**	**56.65**	**0.00**
Species	**310266.30**	**5**	**62053.30**	**120.26**	**0.00**
site*species	**20148.90**	**5**	**4029.80**	**7.81**	**0.00**
Error	43860.10	85	516.00		

Appendix 8: ANOVA tables for Leaf Dry Matter Content (LDMC) across different habitat pairs a) open and edge (OP – ED) b) edge and closed (ED – CL) c) open and closed (OP – CL)

	SS	Degree of Freedom	MS	F	P
a)OP-ED					
Intercept	**30.51**	**1**	**30.51**	**31430.19**	**0.00**
Site	**0.09**	**1**	**0.09**	**91.63**	**0.00**
Species	**1.75**	**16**	**0.11**	**112.61**	**0.00**
site*species	0.02	16	0.00	1.28	0.21
Error	0.25	254	0.00		
b)ED-CL					
Intercept	**20.12**	**1**	**20.12**	**13167.34**	**0.00**
Site	0.00	1	0.00	0.35	0.56
Species	**0.32**	**8**	**0.04**	**26.43**	**0.00**
site*species	0.02	8	0.00	1.72	0.10
Error	0.22	145	0.00		
c)OP-CL					
Intercept	**12.42**	**1**	**12.42**	**8656.60**	**0.00**
Site	**0.03**	**1**	**0.03**	**20.14**	**0.00**
Species	**0.16**	**5**	**0.03**	**22.49**	**0.00**
site*species	**0.02**	**5**	**0.00**	**3.13**	**0.01**
Error	0.12	85	0.00		

Appendix 9: ANOVA tables for Leaf Area (LA) across different habitat pairs a) open and edge (OP – ED) b) edge and closed (ED – CL) c) open and closed (OP – CL)

	SS	Degree of Freedom	MS	F	P
a)OP-ED					
Intercept	**529541.10**	**1**	**529541.10**	**2248.59**	**0.00**
Site	**7861.50**	**1**	**7861.50**	**33.38**	**0.00**
Species	**256641.50**	**16**	**16040.10**	**68.11**	**0.00**
site*species	**14044.30**	**16**	**877.80**	**3.73**	**0.00**
Error	59816.80	254	235.50		
b) ED-CL					
Intercept	**245024.60**	**1**	**245024.60**	**1862.65**	**0.00**
Site	498.10	1	498.10	3.79	0.05
Species	**35845.00**	**8**	**4480.60**	**34.06**	**0.00**
site*species	399.50	8	49.90	0.38	0.93
Error	19074.20	145	131.50		
c)OP-CL					
Intercept	**84982.24**	**1**	**84982.24**	**775.12**	**0.00**
Site	**3287.01**	**1**	**3287.01**	**29.98**	**0.00**
Species	**12600.09**	**5**	**2520.02**	**22.99**	**0.00**
site*species	316.81	5	63.36	0.58	0.72
Error	9319.18	85	109.64		

Appendix 10: Anova tables for Community Weighted Mean (CWM) of leaf functional traits weighted by relative density in different habitats. a) Leaf Mass per Area (LMA); b) Leaf Dry Matter Content (LDMC); and c) Leaf Area (LA).

	SS	Degree of freedom	MS	F	P
a) LMA					
Intercept	**212431.000**	**1**	**212431.000**	**557.030**	**0**
Habitat	2182.400	2	1091.200	2.861	0.096
Error	4576.400	12	381.400		
b) LDMC					
Intercept	**2.250**	**1**	**2.250**	**2260.178**	**0**
Habitat	0.002	2	0.001	1.123	0.357
Error	0.012	12	0.001		
c) LA					
Intercept	**49106.650**	**1**	**49106.650**	**65.605**	**0.000**
Habitat	2512.820	2	1256.410	1.679	0.228
Error	8982.260	12	748.520		

Appendix 11: Anova tables for Community Weighted Mean (CWM) of leaf functional traits weighted by relative cover in different habitats. a) Leaf Mass per Area (LMA); b) Leaf Dry Matter Content (LDMC); and c) Leaf Area (LA).

	SS	Degree of freedom	MS	F	P
a) LMA					
Intercept	**0.004**	**1**	**0.004**	**360.379**	**0**
Habitat	**0.000**	**2**	**0.000**	**4.621**	**0.0325**
Error	0.000	12	0.000		
b) LDMC					
Intercept	**2.891**	**1**	**2.891317**	**2949.305**	**0**
Habitat	0.000	2	0.000161	0.164	0.850
Error	0.012	12	0.00098		
c) LA					
Intercept	**19587.140**	**1**	**19587.140**	**190.408**	**0**
Habitat	**2032.610**	**2**	**1016.300**	**9.880**	**0.004**
Error	1028.690	10	102.870		