Understanding the ecological strategies and habitat association of invasive species of Northern Western Ghats and Konkan

A Thesis

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by

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CERTIFICATE

This is to certify that this dissertation entitled "Understanding the ecological strategies and habitat association of invasive species of Northern Western Ghats and Konkan" towards the partial fulfilment of the BS-MS dual degree programme at the Indian Institute of Science Education and Research, Pune represents the study/work carried out by Akanksha Ingale at Indian Institute of Science Education and Research under the supervision of Dr Deepak Barua Professor, Department of Biology, during the academic year 2022-2023.

Dr Deepak Barua

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Dr Deepak Barua

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This thesis is dedicated to my family and friends

DECLARATION

I hereby declare that the matter embodied in the report entitled Understanding the ecological strategies and habitat association of invasive species of Northern Western Ghats and Konkan are the results of the work carried out by me at the Department of Biology, Indian Institute of Science Education and Research, Pune, under the supervision of Dr Deepak Barua and the same has not been submitted elsewhere for any other degree

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ABSTRACT

Ecological strategies are adaptations and mechanisms that help plants maintain their ecosystem function. Ecological strategies are closely related to the traits. Traits are measurable and observable characteristics of organisms that are shaped by genetic and environmental factors. However, is there any specific trait combination associated with invasive species? Are these traits related to their invasion success? Moreover, is there a relationship between these traits and the habitat they occupy?

We try to answer these questions in our study. This study aims to look at different ecological strategies of seventy-two invasive species found in the Northern Western Ghats and Konkan (NWGK), using the Leaf-Height-Seed mass (LHS) scheme. Leaf-height-seed (LHS) is a plant ecological strategy scheme that uses Specific leaf area (SLA), Maximum Height (Hmax) and Seed mass (SM) to express meaningful difference in ecological behavior between plant species. We also examined the association between individual traits and trait combinations with Invasion success. We were finally focused on the habitat-traits association.

The result of our study shows that invasive species mainly differ in their competitive and establishment strategies, which are captured by combinations of Height-Seed mass. We found less variation in these species' resource acquisition strategy (Specific leaf area). SLA was found to be associated with invasion success. We found that the human habitat was this region's most preferred habitat for invasive species. There are some species with specific trait combination absent from a particular habitat.

Invasive plant species in the NWGK region with higher specific leaf area are more likely to become widespread. Some trait combination are not suppoted in particular habitats of NWGK region.

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CONTRIBUTION

Contributor name	Contributor role
Akanksha Ingale, Dr Deepak Barua, Megha Ojha	Conceptualization Ideas
Akanksha Ingale, Dr Deepak Barua, Megha Ojha	Methodology
R v3.3.3(R Core Team (2021)	Software
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---	Visualization
Dr Deepak Barua	Supervision
---	Project administration
---	Funding acquisition

INTRODUCTION

Species not native or indigenous to a particular area are called invasive. There are three stages of invasion- introduction, when species are transported across a geographical barrier; naturalization, when the species overcome different biotic and abiotic factors and can reproduce on their own; invasion, when offspring can spread to a distant area away from the introduction site (Puth and Post, 2005). Invasive species are the subset of naturalized plants that produce many offspring at a considerable distance from the parent plants or site of introduction(Richardson *et al.*, 2000).

If a species has a significant ecological, environmental and economic impact, then the species is considered invasive(Caldwell et al.,2006). Invasion contributes to biodiversity loss (Pyšek & Richardson, 2010). Biological invasions negatively affect human and animal health and economic growth (Pyšek et al., 2020; Simberloff et al., 2013). Increasing awareness about the invasion and their plausible impact led to efforts to identify attributes that can help to predict invasion(Reichard & Hamilton, 1997; Rejmánek, 2000; Rejmánek & Richardson, 1996). According to Elton, most successful invaders or non-native species possess the traits that encourage efficient reproduction and spreading, a greater ability to compete, and the capacity to fill unoccupied niches (Elton, 1958).

The performance of species in a given ecosystem depends on its traits. Invading species are thought to have unique characteristics that enable them to take advantage in communities (Elton, 1958). Functional traits are defined as morphological, physiological, structural or behavioural characteristics that affect the performance or fitness of the organisms (Nock et al., 2016). In a functional trait-based method, a species' ecological and evolutionary history is integrated to predict its influence and impact on the ecosystem (Kaushik et al., 2022).

Plant ecological strategy scheme (PESS) consists of a set of traits that help a plant survive, reproduce, compete and coexist with others. Ecological strategies help plants to optimize their resource usage and acquisition in a limited resource environment (Araujo da Costa et al., 2020). One goal of PESS is to understand the different factors that influence plant ecologies (Westoby, 1998). There are many proposed PESSs like “vital attributes” (Noble & Slatyer, 1980), that classify species based on which life history phase presents at different years after repeated disturbance. In response to pressure from cattle grazing, (Dyksterhuis, 1949) classified species based on their response to grazing. The life-form scheme by Raunkiaer classifies plants on where the growth points are when new growth appears following the unfavourable season of the year. The Grime CSR strategy stands for the "Competitive-Stress-Tolerant-Ruderal" strategy, which is a framework used in ecology to categorize plant species into three functional groups based on their response to stress and disturbance. Grime C.S.R. triangle focused on disparities in how coexisting species use a site, as well as between species that inhabit locations with varying degrees of favourability and varied levels of disturbance within a landscape (Westoby et al., 2002). Leaf-height-seed (LHS) is a PESS that uses Specific leaf area (SLA), Height (Hmax) and Seed mass (SM) for the species classification.

Ecologists have proposed different sets of traits associated with critical ecological strategies (Westoby et al., 2002a). However, most ecologists prefer three characteristics—seed mass, specific leaf area or leaf mass per area, and height—(Vendramini et al., 2002; Weiher et al., 1999; Wilson et al., 1999). These traits are fundamental trade-offs in determining plant strategies. Specific leaf area shows the variation in which plants react to rapid growth opportunities, height and seed mass, reflecting various ways to cope up with disturbance (Westoby et al., 2002). LHS scheme is an ecological plant strategy that includes these three criteria.

SLA is similar to an anticipated investment return rate; a high SLA allows for (assuming favourable conditions) a faster return on each gram of dry matter put in a leaf (Poorter, 1994). Plant with faster turnover enables more adaptable in response to the uneven distribution of soil and light resources. Species with high SLA can have strategies which lead to, during early life, rapid leaf creation (Grime,1994). In the absence of nutritional stress, species with larger specific leaf areas often grow quicker and photosynthesize more effectively under low light conditions (e.g. forest understory habitats). Species with low SLA frequently have slow growth rates relatively and low photosynthesis rates; they invest more in dry matter per leaf and have longer leaf life spans (Wright & Westoby, 2000, Shipley et al., 2005). Native species have lower SLA than invasive species (Banerjee *et al.*, 2021). Invasiveness is promoted by high SLA (Lake & Leishman, 2004;Hamilton et al., 2005).

Plant height at maturity is an essential whole-plant trait that influences plant competitiveness for light (Keddy & Shipley, 1989). The taller species at any given time have a significant advantage because light descends from above (Westoby, 1998).Goodwin et al.,(1999) showed that height is linked to invasiveness. Seed mass expresses the species' chance of getting established in a new area. (Westoby, 1998). Seed mass indicates a tradeoff between survival and colonization (Díaz et al., 2016). Seed mass also demonstrate the ability of seedlings to thrive despite hazards (Westoby, 1998). A regenerative trait like seed mass is correlated to invasiveness (Milbau *et al.*, 2003).LHS scheme includes these three criteria. Plant invasiveness and LHS strategy were found to be correlated (Hamilton et al., 2005).

We can look at the advantage of the LHS scheme when we compare it to other schemes like CSR: it does not prejudge that there are no possible strategies in high-stress and high-disturbance conditions (Westoby, 1998). In Raunkiaer's life form scheme, the boundaries between life forms are not prominent and also, species can change life form based on habitat and age (Adamson, 1939).

Changes in land use and land cover (LULC) affect ecosystem processes and services and are a part of global environmental alteration (Nelson et al., 2009; Goldman-Benner et al., 2012). Several socio-economic and biophysical factors, including population increase, agricultural development and intensification, accessibility to infrastructure and markets, water availability, and climate, have contributed to a significant degree of change in LULC during the past years. However, the impact of invasive plant species on LULC dynamics and its effects on ecosystem services at greater geographical scales are little understood (Le Maitre *et al.*, 2014).

Different plant species invade different ecosystems, but alien species are subsets of species that can survive in different habitats (Kalusová et al., 2014, 2017). The characteristics that enable a species to colonize and survive in the plant communities associated with a specific ecosystem might not be favourable in another habitat.

How the plant trait affects the invasion process depends on the invasion stage and habitat. When applied to a different phase of the invasion process or to a different habitat, traits that provide a benefit in a particular stage and/or habitat may be neutral or harmful. Successful invaders have several characteristics that failed invaders lack (Caldwell et al., 2006).

Studies have been done to identify various factors that help a species at different stages of the process of invasion. Lockwood et al. (2005) examined the function of propagule pressure, plant traits and phylogeny in the process of invasion (John R. U. Wilson, 2007). Recent research has shown that these variables frequently interact to influence the success of naturalization and invasion. Studies show that no single characteristics predict a species' success as an invader in a new place (Pysek et al., 1995; Haeuser et al., 2018). Invaders were discovered to have lower C: N ratios and higher N:P and N: N ratios in the foliage. Other than foliar phenolics, leaf and litter traits, leaf palatability and litter decomposability are not affected by invasion (Kurokawa et al., 2010).

Yelenik et al. (2017) examined the impact of soil nutrients and traits on plant invasion. There are also some global studies(Moodley *et al.,* 2013)of the family Proteaceae's invasion ecology which demonstrate that naturalization success was influenced by native range size, root rot susceptibility, and functional traits, while invasion success was influenced by functional traits of species as well as its usage and native range.

In India, Banerjee et al. (2021) looked at different factors influencing the process of naturalization and invasion. They have looked at thirteen variables linked to biogeography, functional trait, introduction pathway, distribution, and use of seven hundred fifteen species. The list of species includes naturalized exotic, cultivated exotic and invasive exotic. They found that the invasive aliens had a substantially more extensive naturalized range, more applications as compared to naturalized and casual aliens. They found that the size of the native and naturalized ranges, different uses, and the growth form directly impacted naturalization's success. At the same time, a longer minimum resident time (MRT) made it easier for naturalized species to overcome the dispersion barrier. In case of individual traits, SLA and height was found to be higher in invasive speceis as compared to naturalised and casual aliens.

But seed mass was greater in casual aliens than naturalised and invasive species. While native range sizes indirectly impacted naturalization and invasion success by affecting the extent of the naturalized range, plant growth types indirectly affected invasion success. Their study focuses on the alien plant species found in India (Pant et al., 2021). Unlike Banerjee et al. (2021), our study mainly focuses on invasive plant species of the Northern Western Ghats and Konkan(NWGK). Instead of just looking at each trait individually and how they vary across different growth forms and invasion categories, we have looked at traits individually and in combination. Also, how these trait combinations differ based on growth form and invasion success and habitat. We compare the trait space of NWGK species with ILORA Invasive species.

The Indian alien flora, ILORA, has data from 22 national and international for 1747 alien vascular plant species for 14 characteristics relating to biogeography, introduction process, distribution, socio-economics, and ecology (Pant *et al.,* 2021).

The Western Ghats is one of four biodiversity hotspots in India (Myers et al., 2000). The Western Ghats significantly affect the preservation of South India's natural balance and cultural and economic advancements. By invading disturbed areas, vacant lands, pastures, farmlands, forests, and plantations, invasive alien weeds have contributed to the decline of the Western Ghats. They have also interfered with afforestation programmes, suppressed native vegetation, and perhaps even led to the extinction of some species. They have also interfered with wildlife management, poisoned domestic and wildlife, increased fire hazards, and decreased the aesthetic value of parks and reserves. Biotic diversity has been significantly decreased, and single-species dominance is shown in regions plagued with invasive alien weeds (Muniappan & Viraktamath, 1993).

Invasive Northern-Western Ghats and Konkan species are less studied than central and southern ghats. Mostly the ecological studies in NWGKs are about endangered species (Bajaru & Manakadan, 2020) or endemic species (Pundarikakshudu Tetali & Sujata Tetali, 2016) or studies on a particular habitat (Watve, 2013a). Patil (2014) has looked at the ecology of three invasive species, *Lantana camara, Chromolaena odorata, and Parthenium hysterophorus,* found in the forest and grassland system of NWGs. Ghate (1991) looked at the origin country, introduction period, mode and place of introduction and habitat invaded by forty invasive species of Western Ghats.

Very few studies focus on trait combinations and habitats of invasive species found in the Northern Western Ghats and Konkan(NWGK).

Our study focuses on the major invasive species of the Northern Western Ghats and the Konkan region. The objectives of the study are:

1) a) Understanding the ecological strategies to determine adaptive strategies of major invasive species of Northern Western Ghats and Konkan using the Leaf-Height Seed mass.

   b) Establishing a relationship between these ecological strategies and invasion success

2) Understanding the distribution and association of these major invasive species with traits across different primary Land Use Land Cover (LULC) categories found in Northern Western Ghats and Konkan

METHODS AND MATERIAL

Study Area

One of India's biodiversity hotspots is the Western Ghats (Myers et al., 2000). It is a chain of mountains that stretches between the latitudes of 8°N and 21°N for around 1600 km and encompasses an area of 160,000 km^2 (Ghats & Ranjit, 1992). The NWGs comprise steep, tall hills of western Maharashtra, Goa and Northern parts of Karnataka; the gently undulating plains of the Konkan climb abruptly to the east from the flat hills of the Northern Western Ghats. The northern western Ghats and the Konkan (NWGK) lie approximately between 15°60' & 20 °75'N (Watve, 2013).

Due to less precipitation and a longer dry season, the northern part of this biodiversity hotspot, along with the Konkan region, significantly differs from its southern and central counterparts (Bhushan K. Shigwan, 2020).

Mumbai and other large cities such as Pune, Kolhapur, Nashik, and Surat are dispersed in the northern Western Ghats and Konkan and cause various anthropogenic pressures.

Species selection

The PhD student Megha Ojha compiled a list of the eighty most invasive species of NWGK. For this exercise, a comprehensive list of four hundred naturalized exotic species was compiled from three different sources: Naturalized alien flora of Indian States (Inderjit et al., 2018b)of states Maharastra and Goa, ENVIS (Invasive Alien Species, n.d.), and MOEFCC. (The Official Website of Ministry of Environment, Forest and Climate Change, Government of India, n.d.).

Four experts from Northern Western Ghats and Konkan were then asked to refer to the list and identify the problematic species of the region.

Data collection

Plant samples were collected from different places along the edge of NWGK. The samples were collected from Laling (20.7979° N, 74.7402° E), Waghapur (18.3968 ° N, 74.1262 ° E), Saswad district (18.3463° N, 74.0302° E), Pune-Sus Hills

(18.5907°N 73.8167°E), Savitribai Phule Pune University (18.5530° N, 73.8265° E), Panchvati Hills or Vetal tekdi (18.5255° N, 73.8154° E), Mulshi(18.5011° N, 73.5138° E), IISER Pune campus(18.5474° N, 73.8080° E), Mogarale (17.8661° N, 74.5288° E), Indian Institute of Tropical Meterology (18.5376 ° N, 73.8053° E) and places around Pune city(18.5204° N, 73.8567° E). The collection was always done under the supervision of a taxonomist to avoid any taxonomic confusion or misidentification of the species.

Primary Data: Plant samples were collected only for sixty-eight species. The collection could not be done for thirteen species because the likely location they could be found was destroyed due to anthropogenic activities. Only mature individuals in their flowering stages were collected for the study. The collection started in September and ended in December. For every species, we tried to collect five replicates. A minimum of three replicates were collected for species where we could not find five replicates. (Supplementary Table 2 include species of both primary and secondary data)

Secondary Data: To supplement primary data, secondary data was also collected. Data were collected from research and review articles ,online databases TRY and ILORA. Secondary data was collected for all eighty species. Data was collected for maximum height and seed mass.

Data is extracted from research and review articles using Google Scholar. For height, keywords "max height" OR "shoot length" OR "height" and for seed mass ", seed mass" OR "seed weight" OR "seed size" OR "seed dimension" were used. Data were also collected on each species' growth forms (herb, shrub, tree, and vine)

ILORA Database is an Indian database for 1747 non-native species of India (Pant *et al.,* 2021) ILORA has trait data for more species, including invasive exotic, which we focus on in this study, and naturalized and cultivated exotic species. We have used ILORA data in our study to compare how their data distribution differs along the LHS scheme. Information used for our study is Specific leaf area (SLA), Max Height(Hmax), and Seed mass (SM). Species which do not have data even for one of these traits are not used in the analysis. Two hundred ninety-four species are used for further analysis. With ILORA, we had sixty-four overlapping species and seven unique species.

Land use land cover (LULC) data- PhD student Megha Ojha extracted this data. LULC data was extracted from (Roy, 2016) of 2005 because it is the most recent available open source data on land use land cover in India. The resolution of data used is 1kmx1km. Major LULC categories in NWGK found after aggregation are Human disturbed, Plantation and agriculture, and Natural habitat. Megha Ojha and I collected Species Occurrence data from different herbaria of NWGs: BLATTER Herbaria(Mumbai), Shivaji University Herbaria (Kolhapur), Botanical Survey of India (Pune), Agharkar Research Institute(Pune).

Data Processing

Herbaceous species were uprooted and brought back to the lab. For each individual, height was estimated. Both the reproductive and the vegetative height were measured in centimetres. For shrubs and trees, height measurement was taken at the site. The Yardstick method was used to measure the height of trees using a stick and a measuring tape. Take an arm-long-length stick. Hold the stick straight at 90 degrees with an outstretched straight arm. Step backwards until the top of the stick and the tree are parallel. The distance between the feet and the tree is roughly equivalent to the tree's height (Height Measurements I BC BigTree, n.d).

Five healthy leaves were collected from five mature individuals to measure each species' leaf traits. The samples are kept overnight for hydration before processing. Fresh weight was measured for every leaf. Leaves were scanned using the Canon i110 Scanner. Leaf area is calculated using the scanned image with the help of ImageJ software. The images were first converted to binary, then the area was calculated, but we used the find edges method for some species with very small leaves (ImageJ user guide - IJ 1.46R 2023).

After fresh weight, the leaves were kept in a Hot Air Dryer for three days at 80 degrees Celsius. After three days, dry weight was measured for every leaf.

Using the fresh weight and dry weight information, leaf dry matter content (LDMC) was calculated, which is the oven-dry mass(mg) by fresh water-saturated mass(g) of a leaf. From leaf area and dry weight SLA, calculated by the area of one side of the fresh leaf divided by its oven-dry mass. SLA is reciprocal of leaf mass per area (LMA) ("Corrigendum: New Handbook for Standardised Measurement of Plant Functional Traits Worldwide (Australian Journal of Botany (2013) 61:3 (167-234) DOI: 10.1071/BT12225)," 2016. All the seed mass data was collected from the secondary literature.

Data Analysis

The Shapiro-Wilk normality test is performed on all traits to check for normality. Since the traits were not normally distributed, all trait values were log-transformed. After transformation, the Shapiro-Wilk normality test was used again to ensure the traits were normally distributed (p-value- ~>= 0.05). All analyses were performed on these log-transformed data. We performed a few bivariate analyses using Pearson's correlation to examine the relationship between these traits.

Principal component Analysis (PCA) was used to understand the trait combinations of seventy-two species based on the LHS scheme.PCA is a statistical method used to reduce dimensionality and identify most important variables that explains the majority of variance in data. In PCA each feature or variable is represented by a vector in the transformed coordinate system. The length and direction of the vector represent the magnitude and direction of the feature's variation in the dataset.The specific vectors in the PCA figures are marked based on their contribution to the principal components. The principal components are the directions of maximum variance in the dataset and are determined by calculating the eigenvectors of the covariance matrix of the data. Each eigenvector represents a principal component, and the corresponding eigenvalue represents the amount of variance explained by that principal component. The larger the eigenvalue, the more important the principal component is in explaining the variance in the dataset.

Another PCA was performed on the trait data for the species mentioned in the ILORA database. Subsequently, one-way ANOVA and Tukey HSD posthoc test were used to understand whether the trait combinations differ across growth forms or among data sources. All the analyses were performed using the open-source statistical environment R 3.3.3 (R Core Team (2021). Finally, we also looked at the trait combination of species in primary habitat using PCA. "tidyverse", "factoextra"," patchwork", "ggplot2", and" agricolae" packages are used for PCA.

In order to evaluate the relationship between traits and invasion success, we performed simple linear regression for univariate analysis. We used the trait values as the explanatory variables on X-axis, whereas three proxies of invasion success (Number of grids, Extent of occurrence and Area of Occupancy) were used as a response variable on Y- axis. To check for heteroscedasticity in data, studentized Breush- Pagan and Non- constant variance tests are used. Since more occupancy or widespread can result from a longer residence time, we wanted to control the residence time. In order to do that, we used simple linear regression. The residual values were then used as the response variable. Along with individual traits, all the analyses were performed with the PC axis as an explanatory variable to understand the relationship between trait combinations and invasion success. The same analysis is done for all three variables that explain invasion success- the extent of occurrence, the number of grids and the area of occupancy.

1)Extent of occurrence (EOO):is defined by the area within the shortest continuous boundary enclosing all the present occurrences of data, excluding the cases of vagrancy. EOO is calculated using the minimum convex hull method (Mapping Standards and Data Quality for the IUCN Red List Categories and Criteria, 2018).

2)Area of occupancy (AOO):is the area within the extent of occurrence occupied by the taxon, excluding cases of vagrancy. For my work I used Cartographic method by Conglomerate(CMC). The first step is to plot the geo-referenced localities of each species on a map. Then, a minimum spanning tree is created by uniting the closest pairs of points while avoiding forming loops, similar to the Areographic method. The average distance between pairs of points is then calculated using the mean propinquity method. The resulting value is taken as the radius of a circle encircling each point, which allows for identification of disjunct conglomerates of partially overlapping circles and single, isolated satellites.

Next, the area of each conglomerate is calculated separately using the Cartographic method. To define the scale for each conglomerate, the distance between the two most distant points in each conglomerate is measured, and 10% of the maximum distance defines the grid cell size in each conglomerate. The area occupied by the species in each conglomerate is then calculated by adding the grid cell areas where the species is present. Satellites are assigned a constant area of 2 km^2 based on field experience. Finally, the AOO of the species is calculated as the sum of the areas of all its conglomerates and satellites. (Hernández and Navarro, 2007).

3)Number of grids: The area occupied by the species is calculated by adding the grid cell areas where the species is present. The grid size in this case is taken as 10x10 km since the location of occurrence is not accurate.

RESULTS

We did a bivariate analysis using Pearson's correlation to understand the relationship between the traits in the LHS scheme (Table 1). Among all the pairwise comparisons, we found that only Hmax-SM are moderately positively ($p<0.05$, $r=0.623$) related to each other. Other trait correlations Hmax-SLA and SLA-SM, are also significant ($p<0.05$) (Figure 1).

In order to understand the major axes of variance in the data, we performed a Principal component analysis (PCA). In PCA, Dimension 1 explained 62.8% of the variance, and Dimension 2 explained 22.1%. Dimension 1 had a 37% loading of Hmax and 36% loading of SM. Together, Dimension 1 and Dimension 2 explained 84.9% of the total variance in data (Supplementary Figure 2). Hmax and SM decreased along Dimension 1, and SLA increased along Dimension 2. SM and Hmax had similar trends along Dimension 1. A higher PC 1 score represents a lower value of SM and Hmax, whereas a higher SM and Hmax represents a lower PC1 score. Variance in our data is primarily due to different Hmax and SM combinations along Dimension 1 rather than SLA along Dimension 2 (Figure 2). The same analysis was done with seventy-three species, including *Typha domingensis,* and the results were similar (Supplementary Figure 3).

In order to understand where NWGK species fall compared to ILORA Invasive and their trait combinations, we did another PCA (Figure 3). Along Dimension 1 and Dimension 2, no significant differences existed between the trait combinations of the ILORA invasive and NWGK species, which means trait combinations of our species are not uniquely comparable to any one of the ILORA Invasive. There are trait combinations like high Hmax high SM and low SLA which are present in ILORA but absent in NWGK region. There are twenty-four species in common between ILORA invasives and NWGK species. Four of the NWGK invasive species are classified as Naturalized according to ILORA. ILORA consists of species with low SLA, high Hmax and high SM; species of this combination are absent in NWGK.

We looked at the variation in these traits according to their growth form: SLA value decreases from herbs to trees, MaxHeight increases from herbs to trees, and seed mass increases from herbs to trees (Figure 4 A, B, C). ANOVA showed that there is a significant difference between the three growth forms in terms of traits(p-value<0.05).

Growth forms occupied distinct regions in the Dimension1-Dimension2 trait space. Herbaceous species were at the higher end of Dimension1 with higher SLA, low Hmax and low SM, whereas the trees were at the lower end of Dimension1 with higher Hmax and SM. Shrubs&liana occupied an intermediate position (Figure 4 D)

Similarly, like growth form, we looked at the variation in these traits according to their primary habitat. There is no particular pattern of increase or decrease in all the traits. However, there is a significant difference in the SLA of the three habitats. Hmax and SM are not significantly different in these three habitats (Figure 5 A, B, C).

PCA was used to see if a species' habitat preference depends upon its trait combination along Dimension 1 and Dimension 2. Human disturbed and Plantation and agriculture habitat consists of species with combination of high Hmax, high SM and low SLA which is absent in Natural habitat.(Figure 5 D).

The Breush-Pagan and Nonconstant variance tests are used to check the homoscedasticity of invasion success proxies and first date of occurrence (Supplementary Figure 4). Both tests showed that the AOO is homoscedastic (p value>0.05). To understand if the traits of the LHS scheme can explain invasion success (spatial spread), we performed a linear regression analysis where AOO is the response variable, and the trait values were used as an explanatory variable. A significant relationship exists between the AOO and individual trait SLA values (Figure 6). Along with the effect of individual traits on invasion success, we also looked at the relationship between trait combinations (PC axes) and the AOO. No significant relationship was found between AOO and PC axes (Figure 7). To control for the time since the introduction of a species, linear regression was used. After controlling for the first date of occurrence, we found that SLA has a significant relationship with the Residual value of AOO (Figure 8). Similarly, the relationship holds true in the case of trait combination (PC axes). PC2, which has 72 % loading of logSLA, is significantly related to Residual AOO values (Figure 9). For significant relation the R^2 value is very low.

All three invasion proxies found to be positively correlated to the other two invasion proxies. Similarly,like AOO we did the analysis for other invasion proxies- Extent of Occurrence and Number of grids occupied (Supplementary Figure 5, Supplementary Table 1).

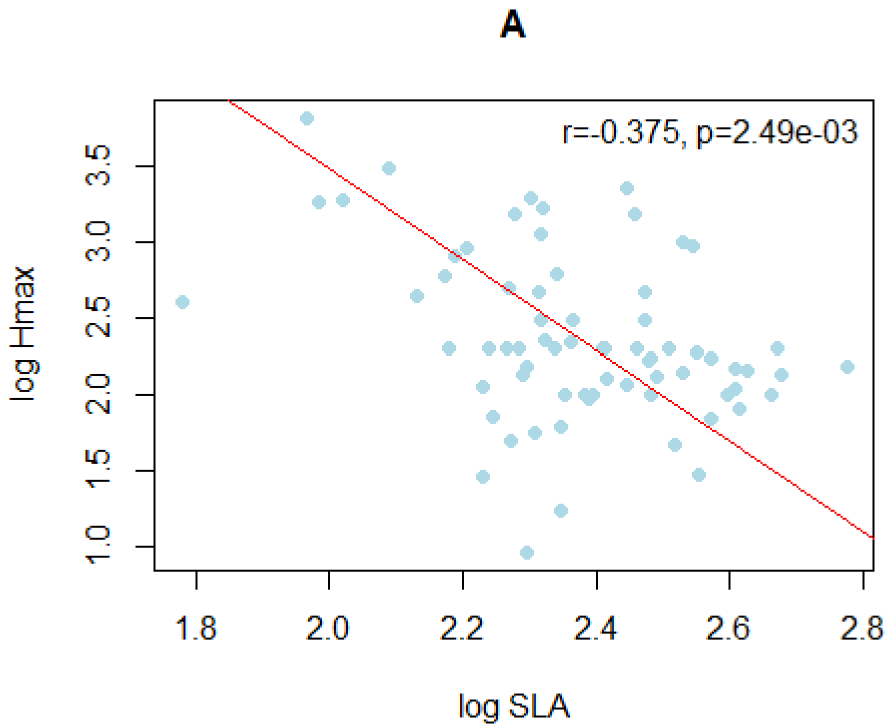
According to the frequency distribution histogram, human-disturbed habitat supports the most number of invasive species, thirty-seven. Natural habitat supports the least number of species (Figure 10).

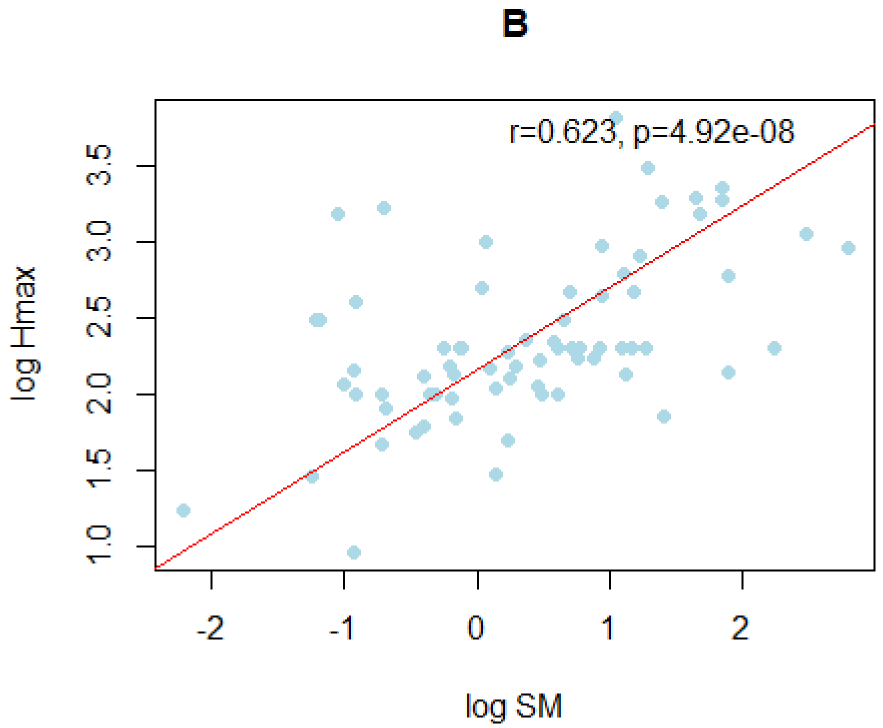
Table 1- Results of significance test and pearson correlation test for bivariate relation of three traits MaxHeight(Hmax), Specific leaf area (SLA), Seed mass (SM). All values are log transformed. p-value shows the significance and r value represents the pearson correlation coefficient Bold value represents the significant relationship.

	p-value	r value
logHmax-logSLA	**<0.0001**	-0.375
logHmax-logSM	**<0.0001**	0.623
logSLA-logSm	**<0.0001**	-0.343

Table 2- Results of linear regression and significance test of individual traits MaxHeight(Hmax), Specific leaf area (SLA), Seed mass (SM) before controlling the first date of occurrence and after controlling for the first date of occurrence for invasion status proxies- Area of Occupancy(AOO). Residual_AOO shows values after controlling for first date of occurene Values in bold shows significant relation.

	AOO	Residual_AOO
logHmax	R^2-0.014, p-0.351	R^2-0.006, p-0.55
logSLA	R^2-0.115, p-**0.006**	R^2-0.129, p-**0.004**
logSM	R^2-0.024, p-0.226	R^2-0.023, p-0.233
PC 1	R^2-0.059, p-0.056	R^2-0.052, p-0.071
PC 2	R^2-0.056, p-0.063	R^2-0.074, p-**0.031**
PC 3	R^2-0.004, p-0.621	R^2-0.013, p-0.38


A
r=-0.375, p=2.49e-03
log Hmax
1.0
1.5
2.0
2.5
3.0
3.5
1.8
2.0
2.2
2.4
2.6
2.8
log SLA


B
r=0.623, p=4.92e-08
log Hmax
1.0
1.5
2.0
2.5
3.0
3.5
-2
-1
0
1
2
log SM

C

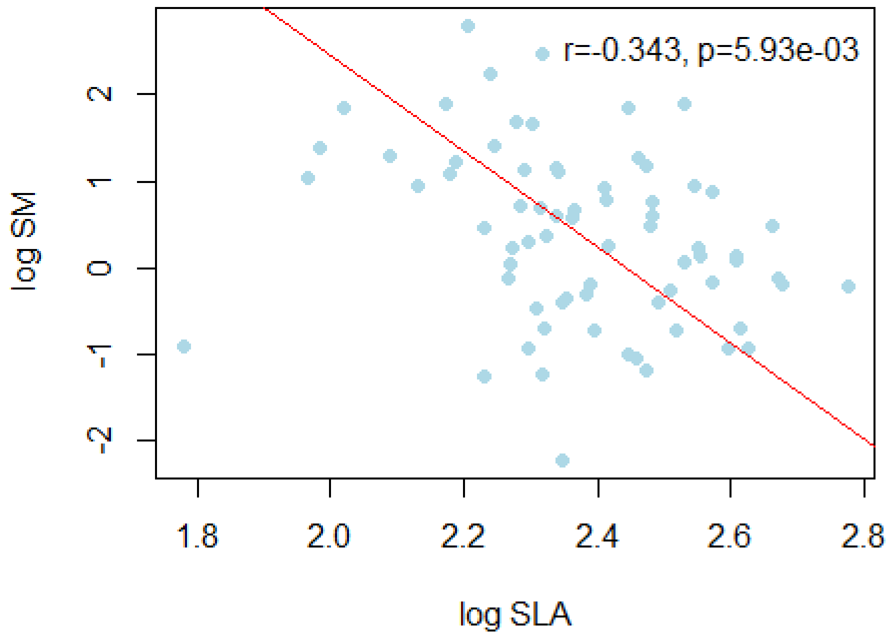


Figure 1: Bivariate relationship between individual traits of Leaf-Height-Seed mass (LHS) Scheme A) logHmax-logSLA B) logSLA-logSM C) logHmax-logSM of seventy two invasive species of Northern Western Ghats and Konkan (NWGK). MaxHeight (Hmax), Specific leaf area (SLA), Seed mass (SM). All traits are log-transformed. Pearson Correlation is used for bivariate analaysis. Each blue point represents one species and their corresponding log transformed trait values. The red line is a type II regression line to look at relationship between two independent variables.

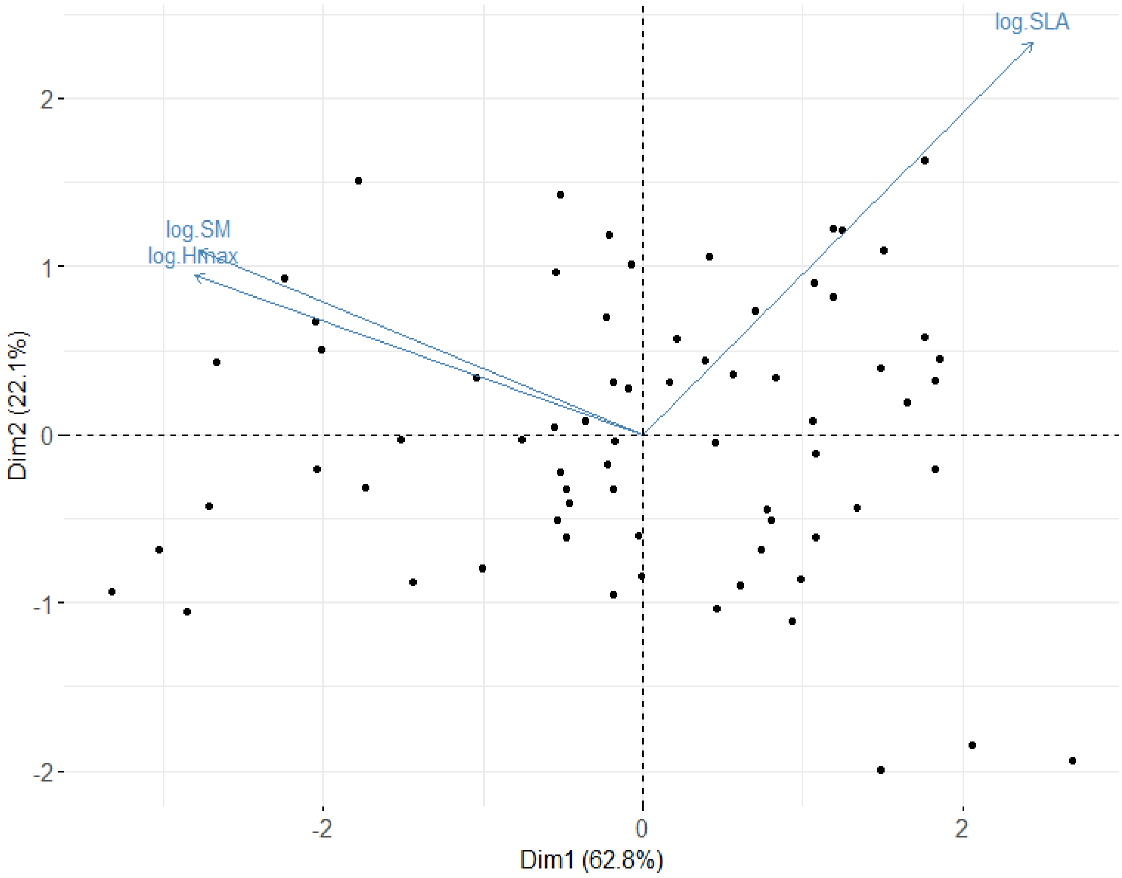


Figure 2: PC Analysis of seventy-two NWGK species based on LHS scheme. Dimension 1 has 37% loading of Hmax and 36% loading of SM; Hmax and SM decrease along Dimension 1, and SLA increases along Dimension 2. Higher PC 1 score represents a lower value of SM and Hmax; comparatively higher SM and Hmax will have a lower PC1 score. Higher PC2 score represents species with comparatively higher SLA. Each feature or variable is represented by a vector in the transformed coordinate system. The length and direction of the vector represent the magnitude and direction of the feature's variation in the dataset.

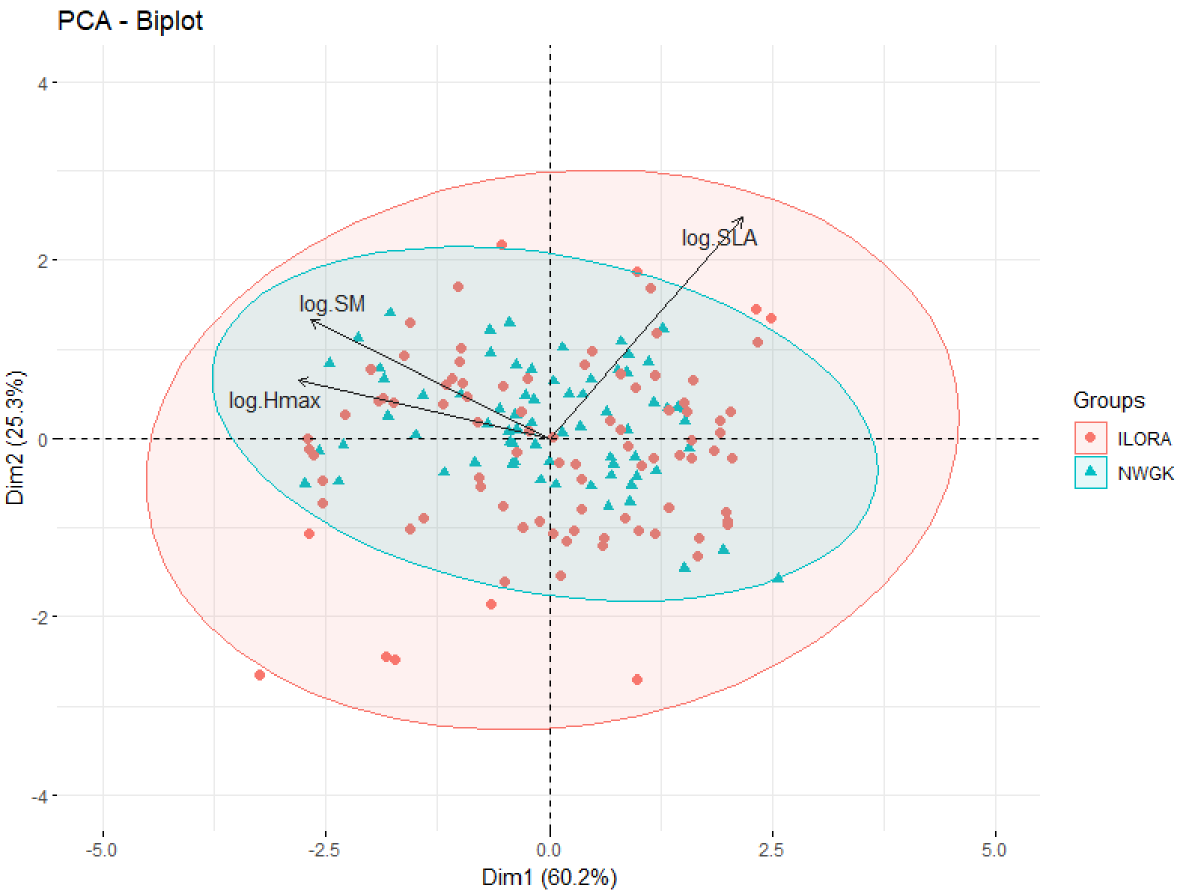
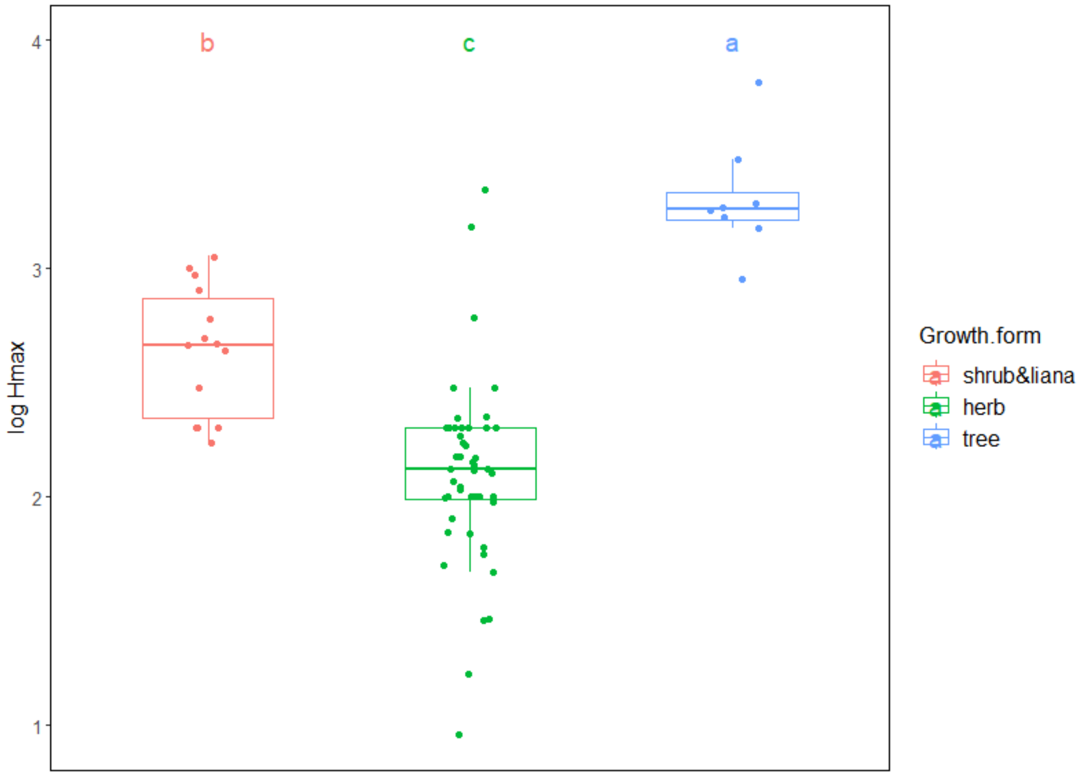


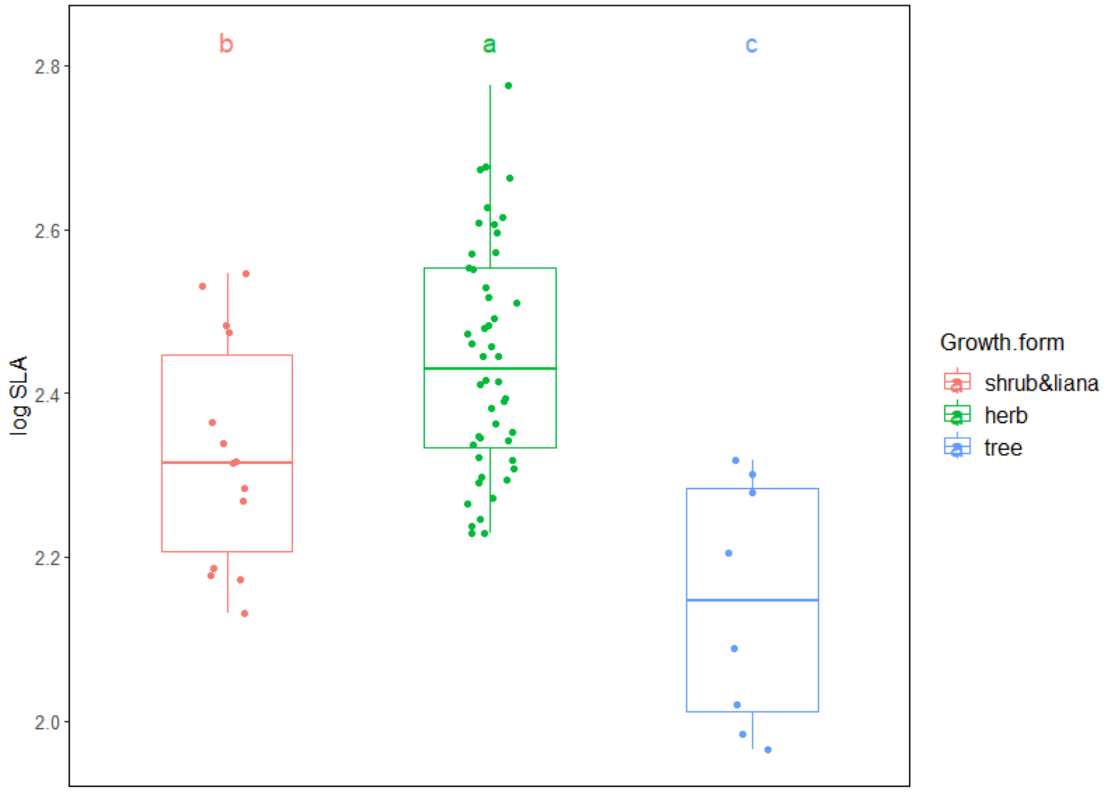
Figure 3: PC Analysis of ILORA invasive and NWGK species on basis of LHS scheme. Red ellipse represents ILORA invasive and blue ellipse represents NWGK species. Dimension 1 explains 59.6% of variance; Hmax and SM decrease along Dimension 1, and SLA increases along Dimension 2. Higher PC 1 score represents a lower value of SM and Hmax; comparatively higher SM and Hmax will have a lower PC1 score. Higher PC2 score represents species with comparatively higher SLA. Each feature or variable is represented by a vector in the transformed coordinate system. The length and direction of the vector represent the magnitude and direction of the feature's variation in the dataset.

A

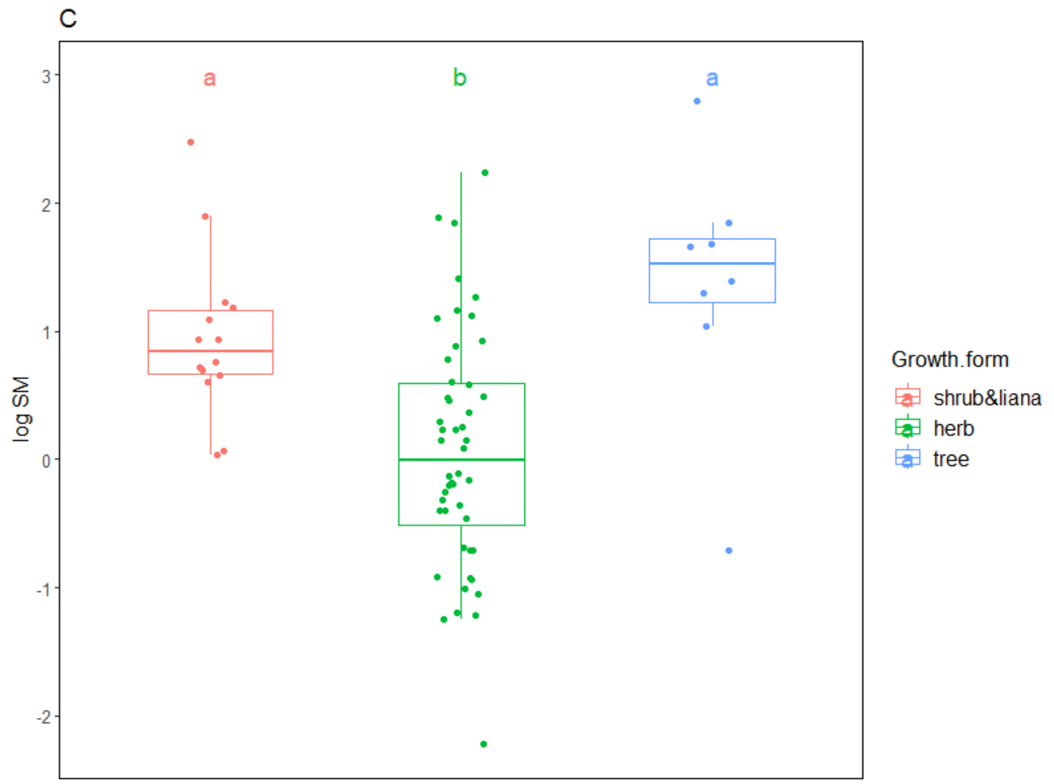


b
c
a
log Hmax
4
3
2
1
Growth.form
shrub&liana
herb
tree

B



b
a
c
log SLA
2.8
2.6
2.4
2.2
2.0
Growth.form
shrub&liana
herb
tree


C
a
b
a
log SM
Growth.form
shrub&liana
herb
tree

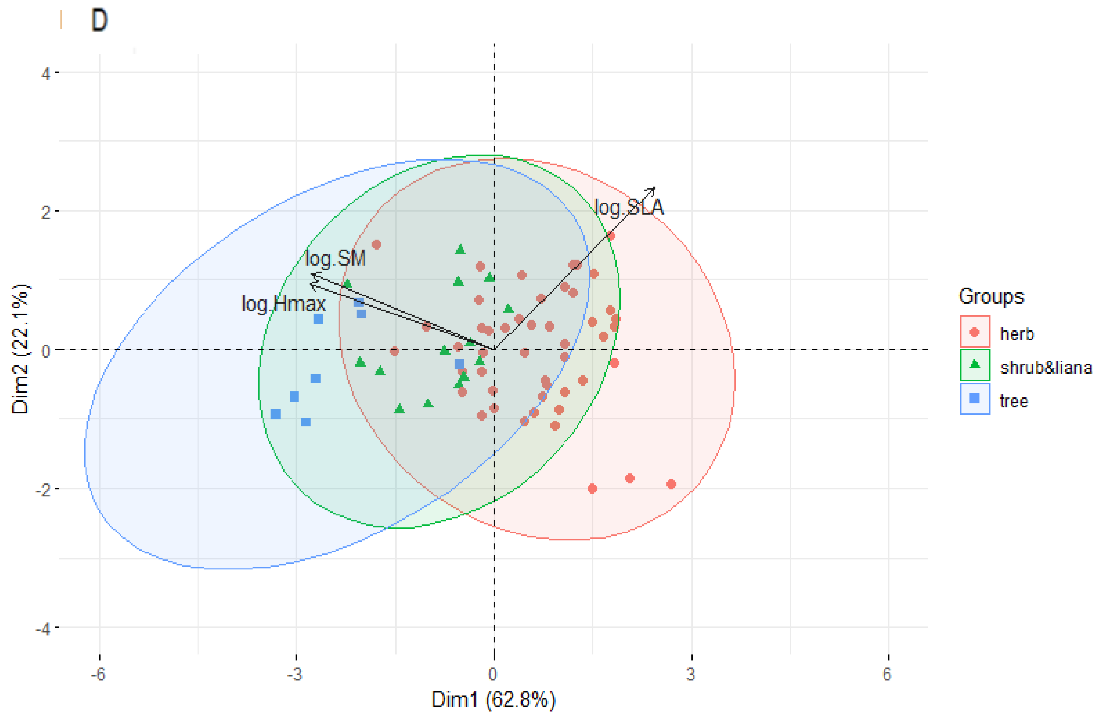
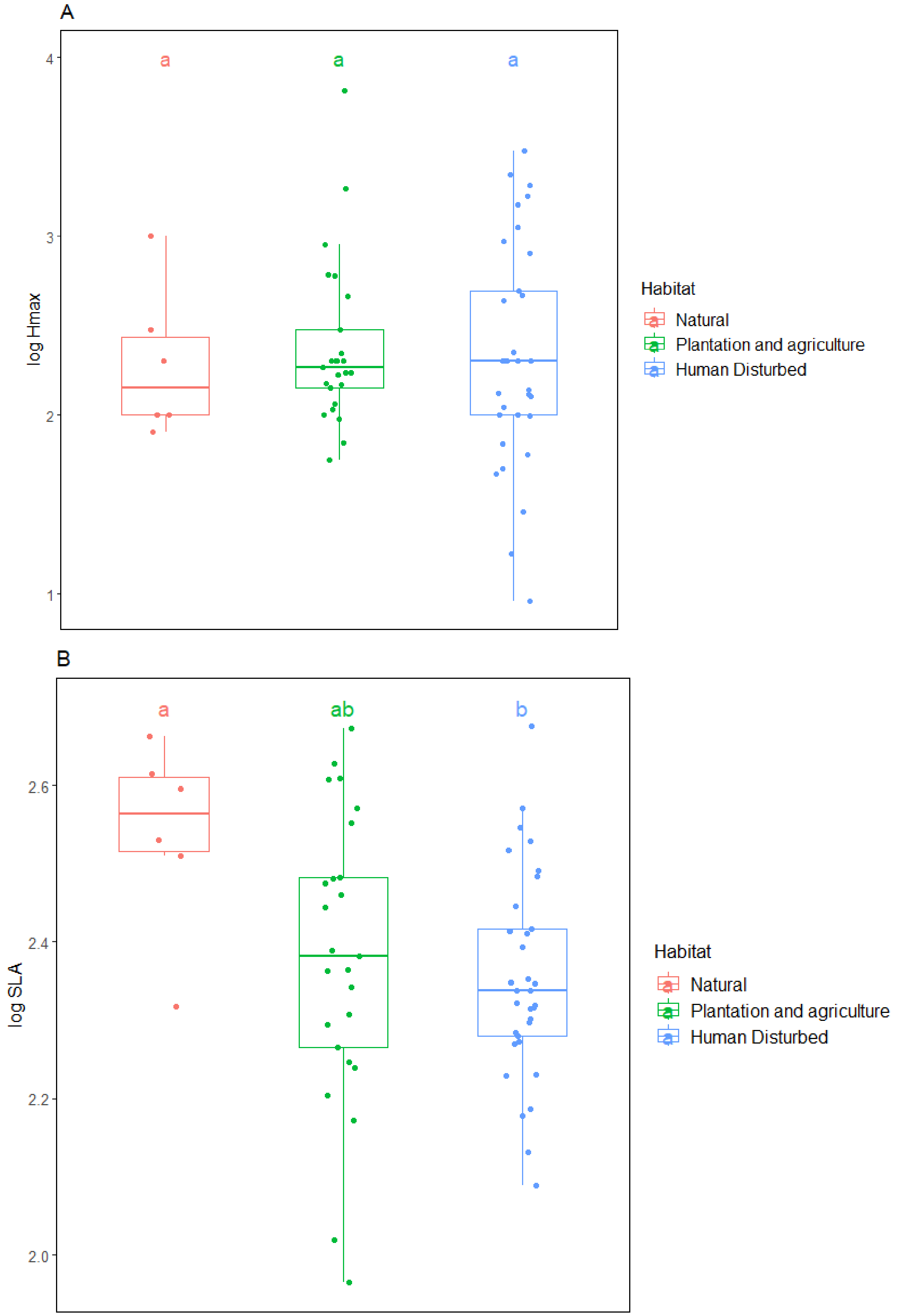
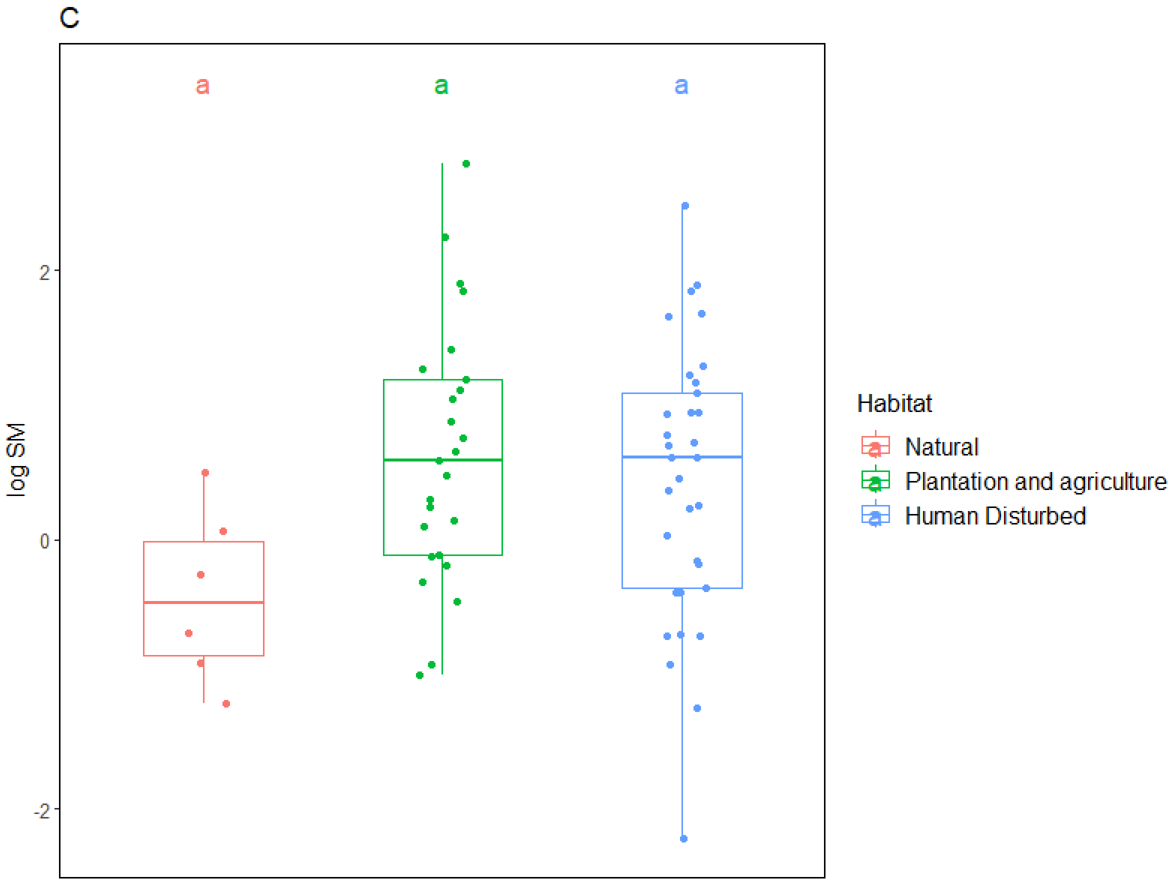

D
log.SLA
log.SM
log.Hmax
Dim2 (22.1%)
Dim1 (62.8%)
Groups
herb
shrub&liana
tree

Figure 4: Representation of variation in three traits A) MaxHeight(Hmax), B) Specific leaf area (SLA) and C) Seedmass(SM) as per their growth form. Red shows herbs, green shows shrubs and liana, blue shows trees. Y axis represent the traits (SLA-cm2/g; MaxHeight- cm, Seed mass-g(1000seeds)). ANOVA is used to determine the difference between the three categories. Alphabets on the top represents the result of Tukey HSD posthoc test. Different alphabet means there is significant different between the groups, similar alphabet means no significant difference. D) NWGK species based on LHS scheme. Ellipse represents the categorization based on growth form: herb, shrub&liana, tree. Ellipses are drawn using 99% confidence level to cover all the points. Red ellipse with circle.represents herbs, green ellipse with triangle represents shrubs and lianas and blue ellipse with square represents trees. Each feature or variable is represented by a vector in the transformed coordinate system. The length and direction of the vector represent the magnitude and direction of the feature's variation in the dataset.



A
a
a
a
log Hmax
4
3
2
1
Habitat
Natural
Plantation and agriculture
Human Disturbed
B
a
ab
b
log SLA
2.6
2.4
2.2
2.0
Habitat
Natural
Plantation and agriculture
Human Disturbed


C
a
a
a
log SM
2
0
-2
Habitat
Natural
Plantation and agriculture
Human Disturbed

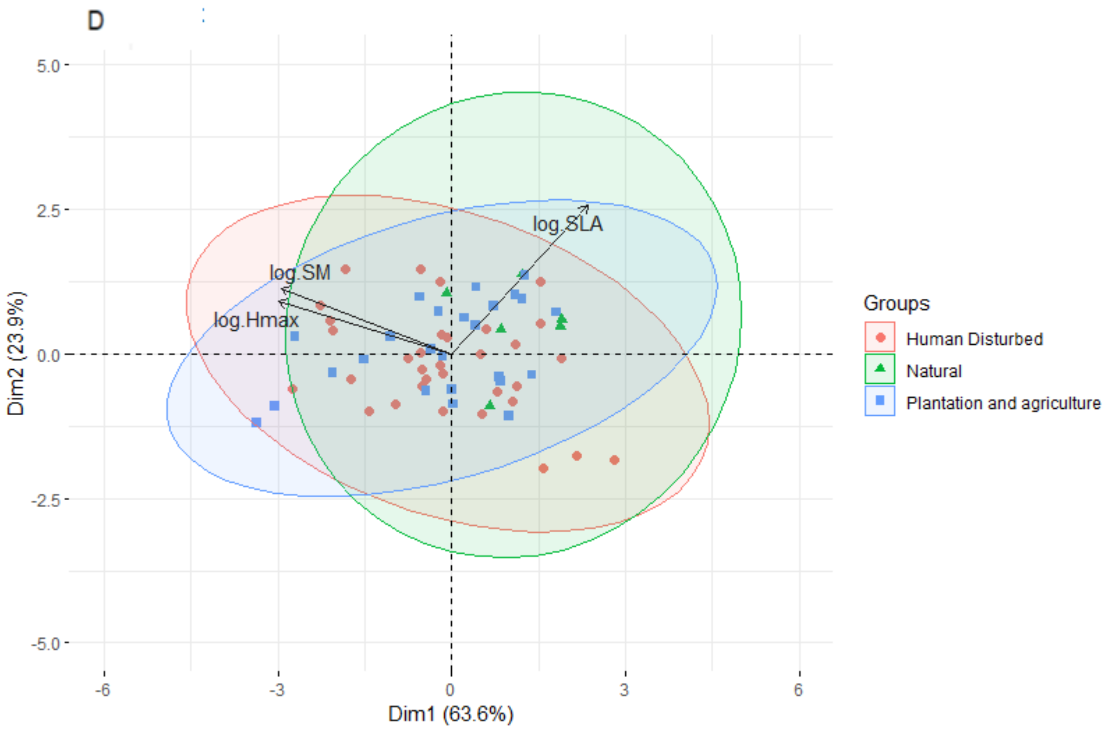

D
5.0
2.5
0.0
-2.5
-5.0
Dim2 (23.9%)
-6
-3
0
3
6
Dim1 (63.6%)
log.SLA
log.SM
log.Hmax
Groups
Human Disturbed
Natural
Plantation and agriculture

Figure 5: Representation of variation in three traits A)MaxHeight (Hmax) B) Specific leaf area(SLA) and C) Seedmass (SM) as per primary habitat. Red shows human dominated, Green shows natural, blue shows plantation and agriculture. Y axis represent the traits (SLA-cm2/g; MaxHeight- cm, Seed mass-g(1000 seeds)). ANOVA is used to determine the difference between the three categories. Alphabets on the top represents the result of Tukey HSD posthoc test. Different alphabet means there is significant different between the groups, similar alphabet means no significant difference.D) NWGK species on basis of LHS scheme. Ellipse represents the categorization based on habitat: Natural, plantation and agriculture ,human disturbed. Ellipses are drawn using 99% confidence level to cover all the points. Red ellipse with circle represents Human disturbed, green ellipse with triangle represents Natural and blue ellipse with square represents Plantation and agriculture. Each feature or variable is represented by a vector in the transformed coordinate system. The length and direction of the vector represent the magnitude and direction of the feature's variation in the dataset.

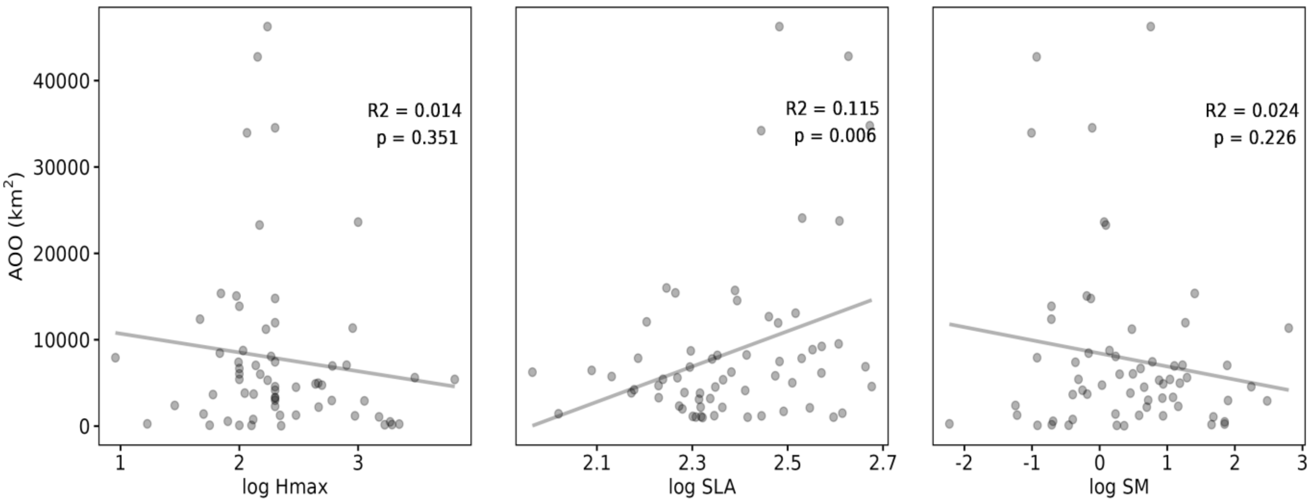


Figure 6: Linear regression between individual traits MaxHeight (Hmax-cm),Specific leaf area (SLA-cm2/g) and Seedmass (SM-g(1000 seeds)) and invasion success proxy Area of Occupancy(AOO-km^2). Relation is significant with logSLA.

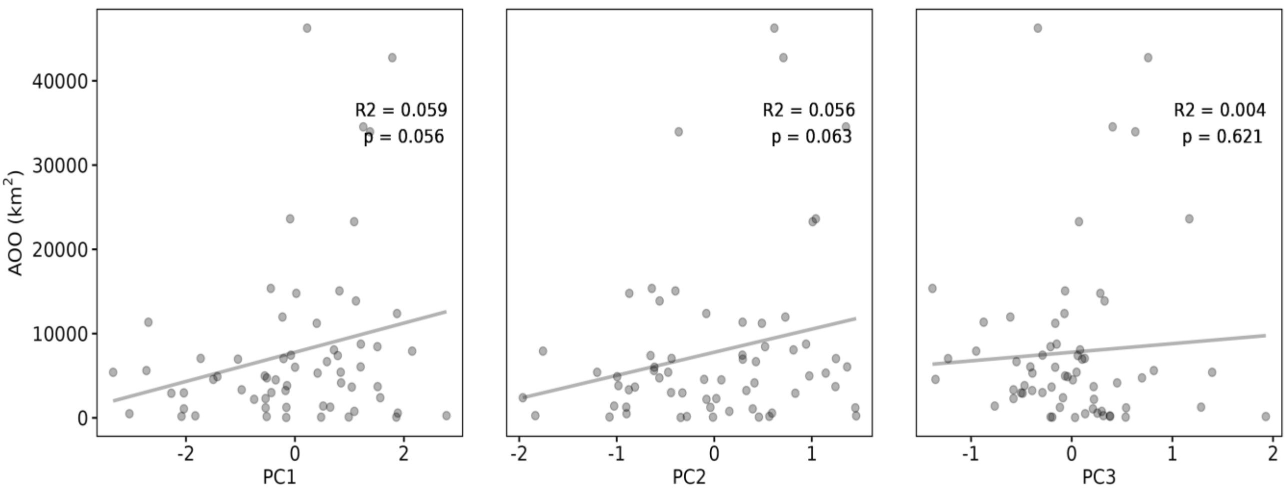


Figure 7: Linear regression between PC axes which have loading from three traits MaxHeight (Hmax-cm),Specific leaf area (SLA-cm2/g) and Seedmass (SM-g(1000 seeds)) and invasion success proxy Area of Occupancy(AOO-km^2). Relation is significant with logSLA. No significant relationship is seen.

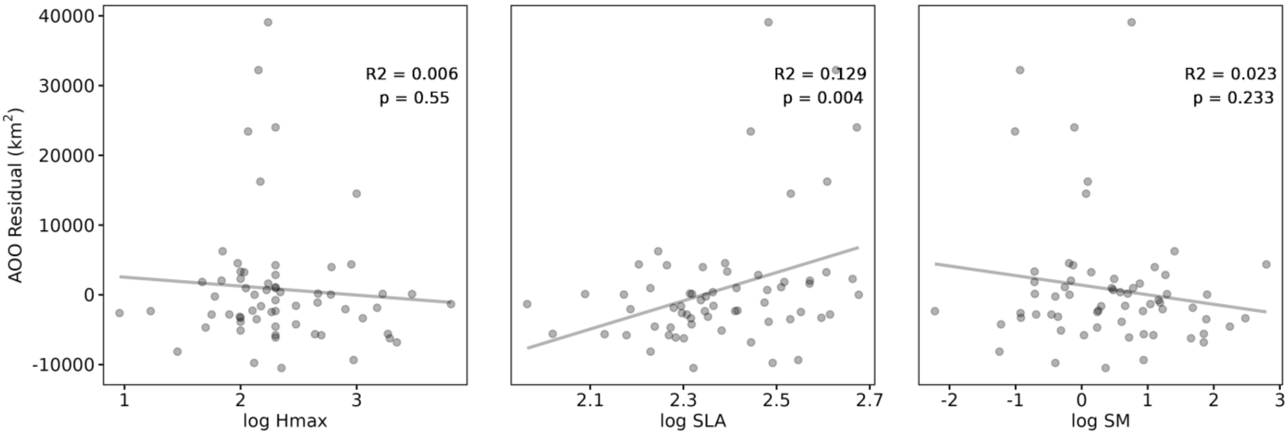


Figure 8: Linear Regression between the Residual values of Area of Occupancy(AOO) which an invasion success proxy and individual traits. Residual values is the difference between the observed AOO value and Predicted AOO value. Relation between Residual_AOO and SLA is significant. All trait values are log transformed.

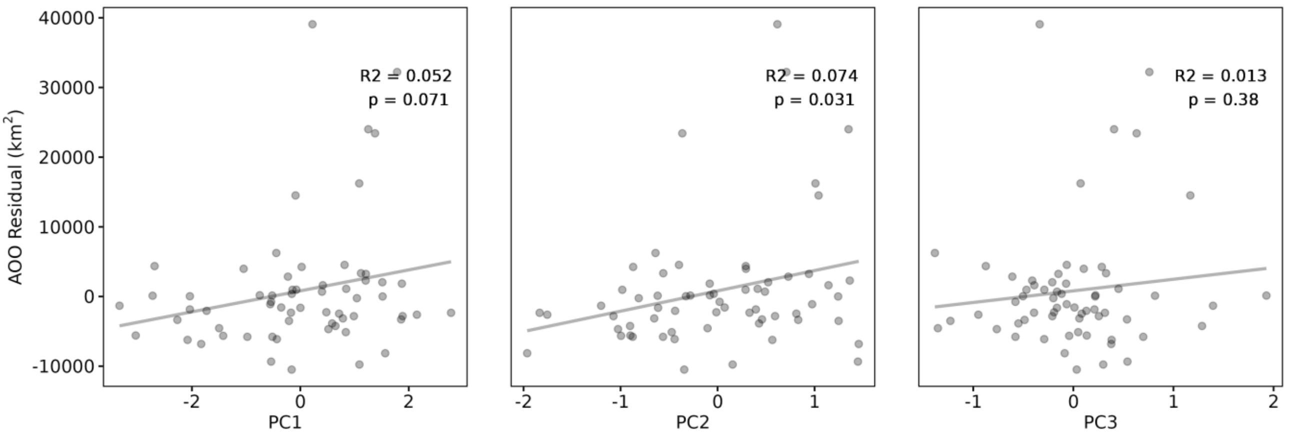


Figure 9: Linear Regression between the Residual values of Area of Occupancy (AOO) which an invasion success proxy and individual traits. Residual values is the difference between the observed AOO value and Predicted AOO value. Relation between Residual_AOO and PC2 is significant. PC 2 has maximum loading of Specific leaf area (SLA).

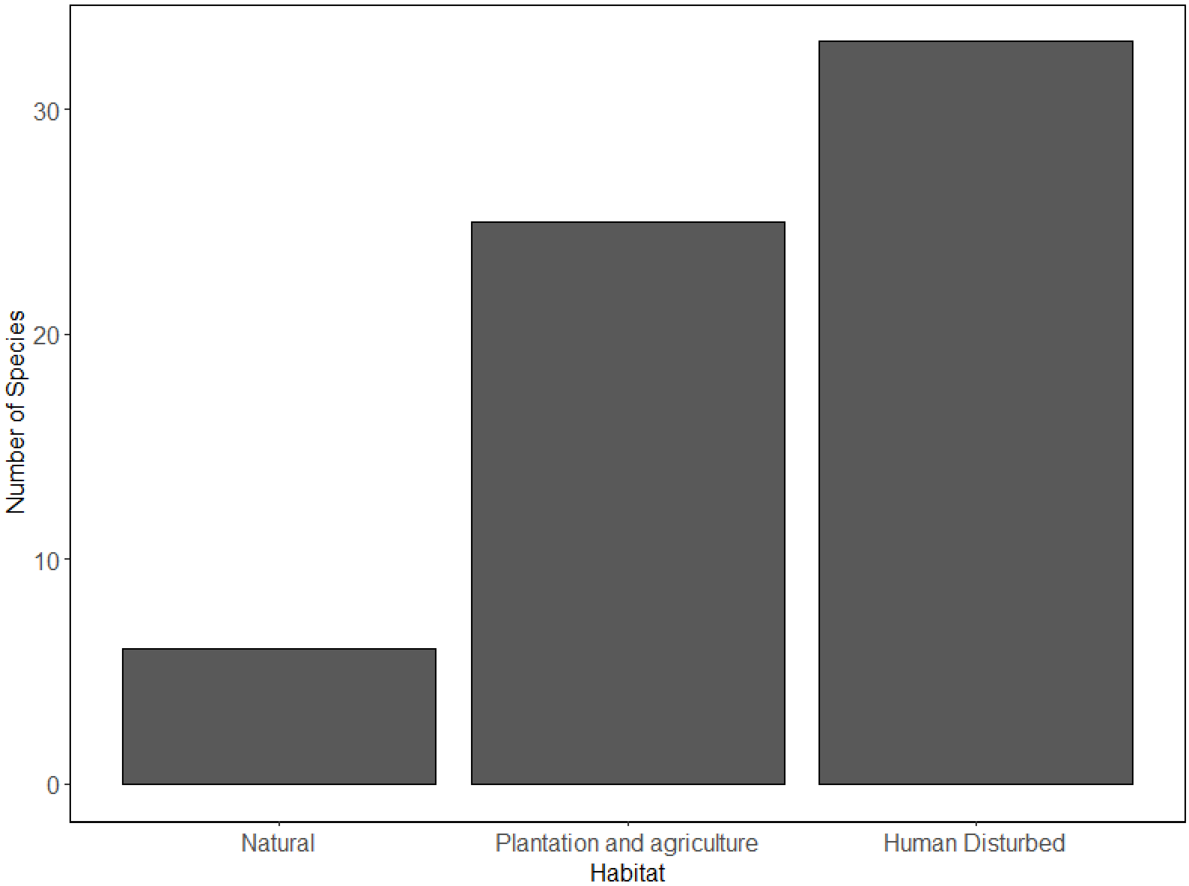


Figure 10: Frequency distribution of species occupying their primary habitat. Primary habitat found in NWGK are Natural, Plantation and agriculture and Human disturbed. Human disturbed habitat support the maximum number of invasive species.

DISCUSSION

Leaf-Height-Seed mass (LHS scheme) is used to understand how plants respond to environmental factors based on their trait combination. SLA represents the resource acquisition strategies of the plant, Maximum Height (Hmax) represents the competitive strategies, and Seed mass (SM) represents the strategies related to the establishment at a new place (Westoby, 1998).

As per the expectation from the LHS scheme, one would expect the three trait axes to be orthogonal and weakly correlated (Westoby, 1998). We find that the assumption holds true for the invasive species of NWGK in the case of Hmax-SLA and SLA-SM, but Hmax-SM shows a strong positive association (Figure 1). However, our result is supported by a recent global study that has shown that seed mass and Hmax are, in fact, positively related across various life forms (Díaz *et al.*, 2016).

NWGK (Figure 2) invasive species mostly varies in their competitive and establishment strategies represented by Hmax and SM, respectively. Invasive species are found to invest more in plant height and other light acquisition-related traits(Tan et al., 2018; Pyšek & Richardson, 2006). However, (Thébaud and Simberloff, 2001) found that aliens generally do seem to be taller in their invasive range. Smaller seed masses are found to be linked with invasion success(Pyšek & Richardson, 2006). Seeds in their non-native range are bigger than those in their native range(Buckley et al., 2003). Banerjee et al. (2021) study shows that invasive across all growth forms non-native invasive speceis are taller than casual aliens and naturalised species but seed mass is not significantly different between the invasive and casual aliens and naturalised species.

We wanted to compare the trait space of ILORA invasive and NWGK species. No significant difference exists between the trait space of ILORA invasive species and NWGK species (Figure 3). ILORA consists of species with low SLA, high Hmax and high SM; species of this combination are absent in NWGK.

After that, we looked at the variation in the trait in different growth forms (Figure 4A, B, C). We then looked at the distributions of NWGK species in the PC trait space based on the growth forms. Herbs mostly clustered at higher PC1, representing lower Hmax and SM; trees are at lower PC1 with high Hmax and SM (Figure 4 D). (Leishman *et al.*, 1995) showed that both Hmax and seed size increases from forbs and grasses to woody species. SLA is higher in herbs than in shrubs&lianas and trees. Herbs have a shorter lifespan and need to produce more leaves to maximize their photosynthetic ability (Poorter et al., 2009).

Similarly, like growth form, we looked at variations in the trait in their primary habitat (Figure 5 A, B, C). Then we looked at habitat and trait associations (Figure 5D). Our results show that species of a particular LHS trait combination prefer no particular habitat. Species from the ILORA database also have the same result (Supplementary Figure 6). Species can have very different habitats independent of their trait combination(Geng *et al.*, 2007, 2016; Pant *et al.*, 2021).

Area of Occupancy is used as an invasion success proxy. Analysis is done with Extent of Occurrence and number of grids as well. All three invasion proxies were found to be correlated and showed the same results.

Analysis showed that SLA has a significant relationship with AOO, a proxy of invasion success (Figure 6). Our result is supported by studies showing that higher SLA tends to be more successful as an invader because of a faster growth rate, short lifespan and rapid turnover of leaf material. (Gallagher et al., 2015; Van Kleunen et al., 2010). No relation between PC axes and invasion success proxy AOO (Figure 7).

Since the species have different residence times, sometimes associated with higher invasion success (Pyšek and Jarošík, 2005; Milbau and Stout, 2008), we controlled for the same using linear regression. Moreover, we found that SLA is related to invasion success after considering the first date of occurrence (Figure 8). Flora *et al.*, (2008) showed that multiple traits can better explain invasion success. So, using PCA, we looked at the relationship between trait combination and AOO (Figure 9). PC2 showed a significant relation with invasion success, which has 72% loading from SLA, positively correlated with invasion success.

Even though the relationship between SLA and invasion success is significant which holds true in case of PC2 and invasion success, but low R^2 value suggest that there can be some other variable which is more strongly related to invasion success.

(Cardador & Blackburn, 2019) Human-mediated dispersal disrupts the biogeographical barrier and allows species in a new region where they can naturalize and cause damage (Van Kleunen et al., 2015). Three major habitats found in NWGK are human disturbed, plantation and agriculture, and Natural. As expected primary habitat for most of the invasive plant species was human-disturbed habitat (Figure 10). Natural and semi-natural communities that have not been disturbed by human activities usually have very few, if any, invasive non-native species that have been introduced recently (Manchester and Bullock, 2000). Human-disturbed habitats can ease the transport and establishment of non-native species (Cardador and Blackburn, 2019). Studies have shown that human-associated habitats exhibit the highest level of invasion (Chytrý et al., 2008).

These finding suggest that Northern Western Ghats and Konkan invasive plant species with higher specific leaf area have are more likely to become widespread than others. Herbaceous species is dominating growth form in invasive species of NWGK. Some specific LHS trait combination were not helpful in making species invasive in NWGK. NWGK invasive speceis can occupy multiple habitats but there are some trait combinations that are not in found in a particular habitat.

CONCLUSION AND FUTURE DIRECTIONS

Species must make certain trade-offs to maximize their fitness in a particular environment. Our study revealed that invasive species of the Northern Western Ghats and Konkan could have various combinations of Hmax-SLA-SM, but they mainly vary in their competitive-establishment strategies. Woody species comparatively have higher height and seed mass than herbaceous species. There are species with certain trait combination that absent in NWGK. SLA, individually and with the combination of other traits, influences the invasion success measured by proxy- Area of occupancy. Finally, our analysis showed that there are some LHS trait combinations are found in human disturbed and plantation and agriculture habitat but not in natural habitat. Human-disturbed areas support the most invasive species, which could be explained by the fact that these areas are highly disturbed and therefore act as a perfect habitat for establishing these species

Potential future avenues may involve investigating the association between invasive species trait combination and their corresponding climatic niches.Also, using different Plant ecological strategy scheme to understand ecological strategies of the invasive plant species. Additionally, the habitat-trait relationships, as discovered in the Northern Western Ghats and Konkan regions, could be tested across different land use and land cover categories throughout India.

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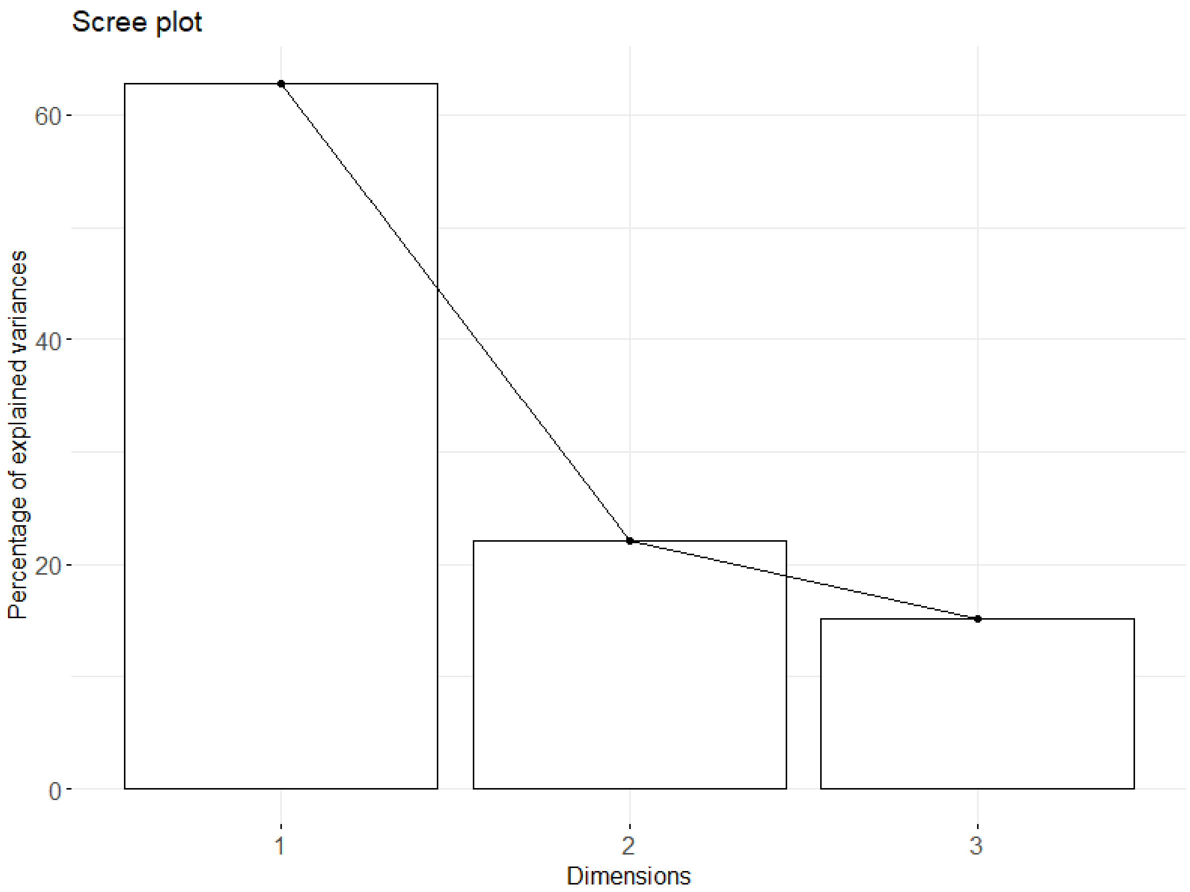
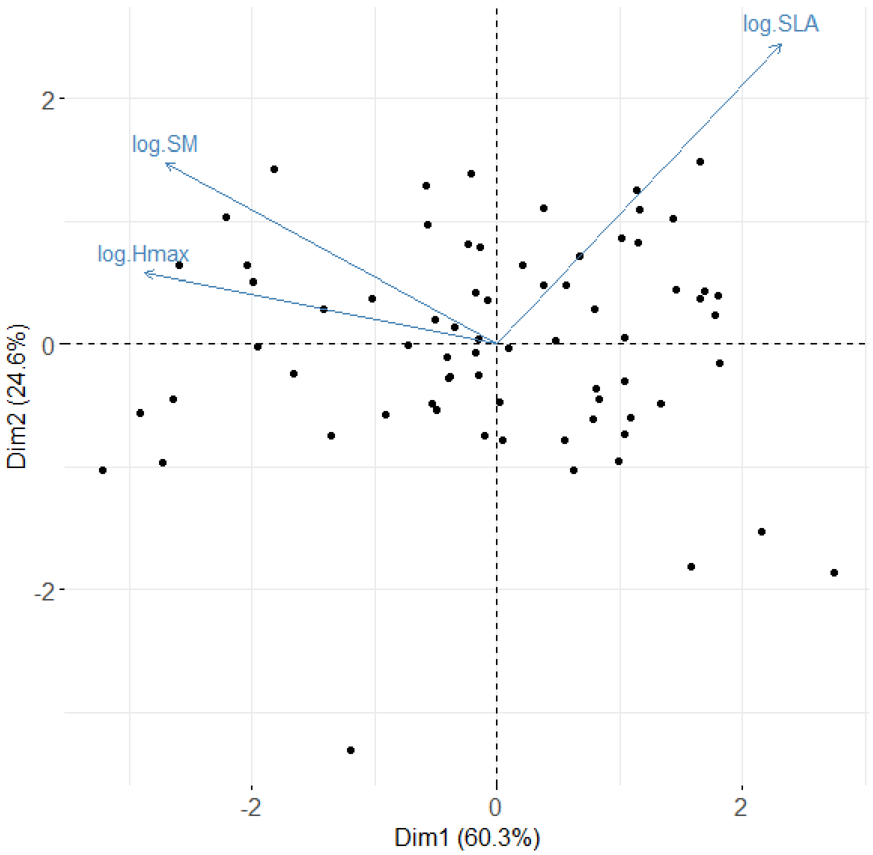
SUPPLEMENTARY MATERIAL

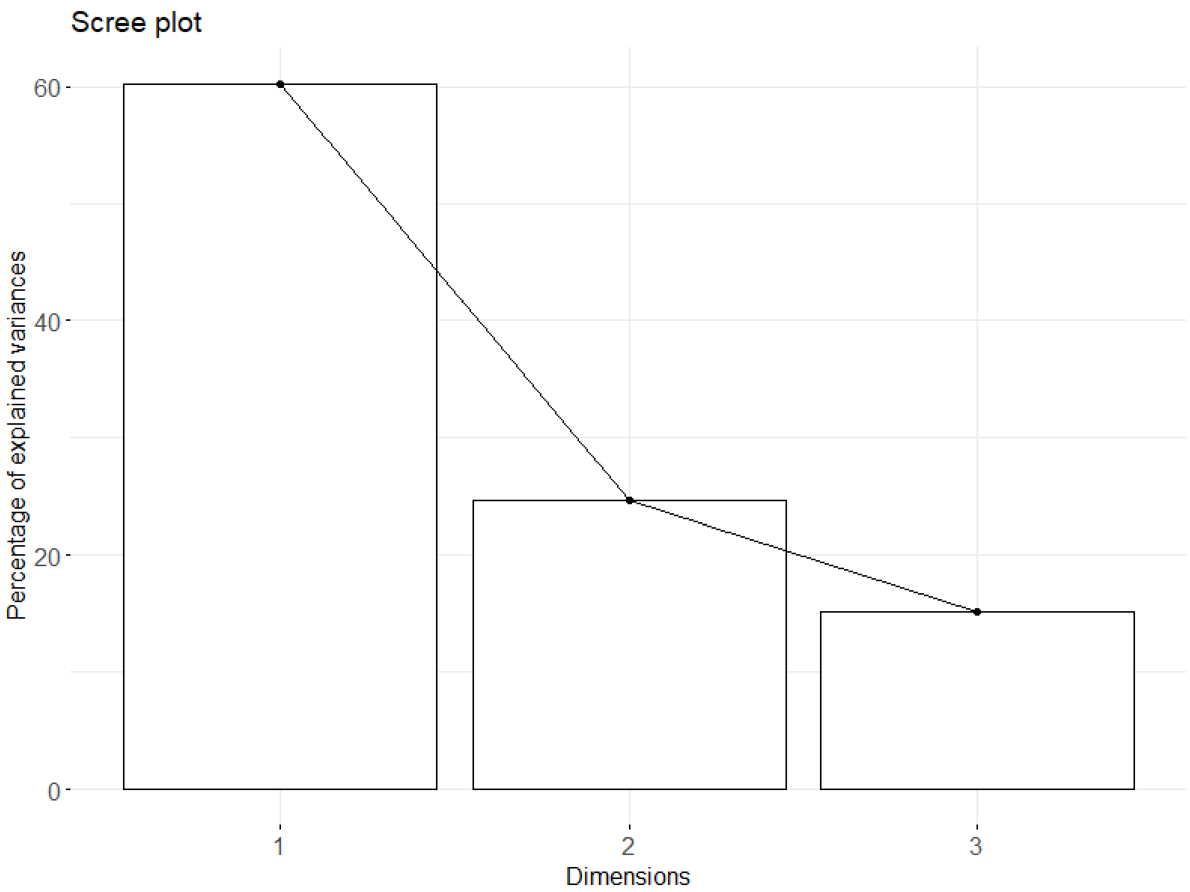
Supplementary Figure 1: Images of collection site Saswad and Laling


Scree plot
Percentage of explained variances
60
40
20
0
1
2
3
Dimensions

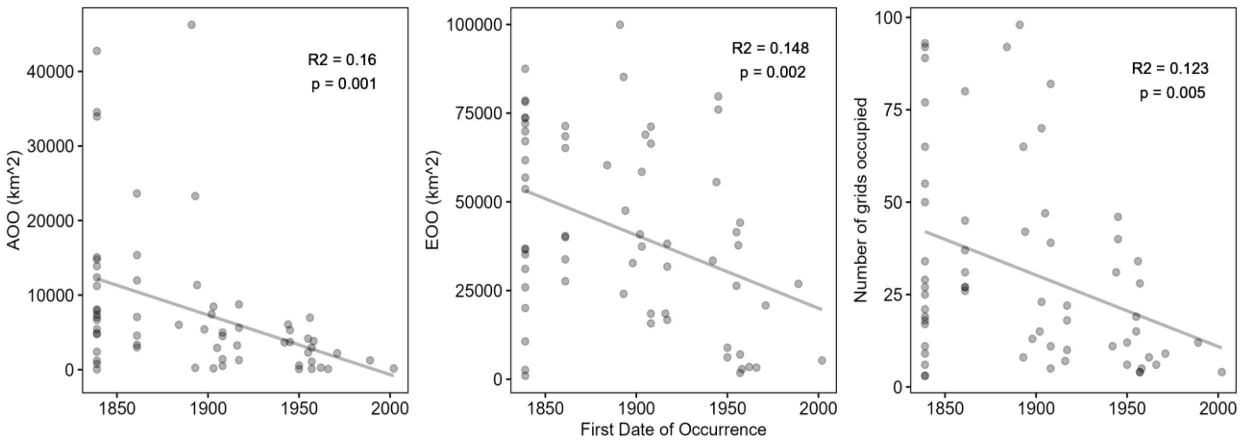

Dim1
Contributions (%)
30
20
10
0
log.Hmax
log.SM
log.SLA
Dim2
Contributions (%)
60
40
20
0
log.SLA
log.SM
log.Hmax
Dim3
Contributions (%)
50
40
30
20
10
0
log.Hmax
log.SM
log.SLA

Supplementary Figure 2: PC analysis excluding *Typha domingensis*. Scree plot showing the percentage of variance explained by the three dimensions. Contribution plot shows the loading of variables on Dimension 1, Dimension 2 and Dimension 3. Dimension 1 has maximum loading from Maxheight (Hmax) and Seed mass (SM). Dimension 2 hs maximum loading from Specific leaf area (SLA)


log.SLA
log.SM
log.Hmax
2
0
-2
Dim2 (24.6%)
-2
0
2
Dim1 (60.3%)

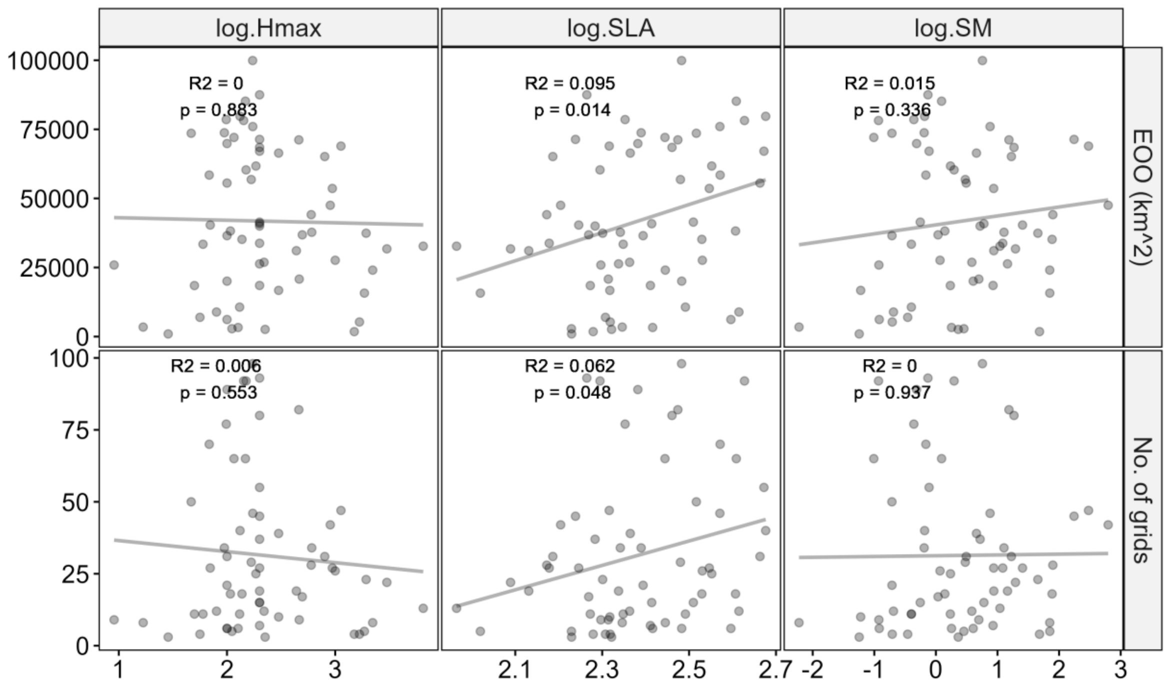

Scree plot
60
40
20
0
Percentage of explained variances
1
2
3
Dimensions

Supplementary Figure 3: PC analysis including *Typha domingensis*. Scree plot showing the percentage of variance explained by the three dimensions. Contribution plot shows the loading of variables on Dimension 1, Dimension 2 and Dimension 3. Dimension 1 has maximum loading from Maxheight (Hmax) and Seed mass (SM). Dimension 2 hs maximum loading from Specific leaf area (SLA). Including Typha changes the percentage of variance and contribution to Dimensions

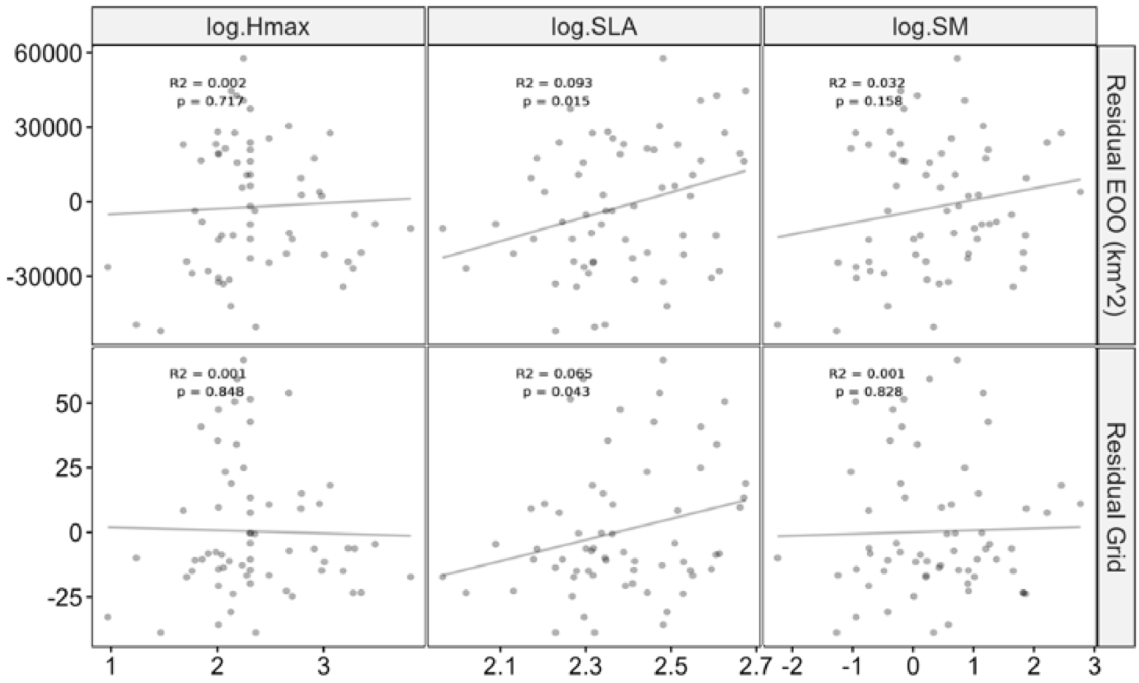


Supplementary Figure 4: Linear regression analysis between three different invasion proxies Area of Occupancy(AOO), Extent of Occurrence (EOO) and Number of grids with first date of occurrence. All three relations are significant.

A



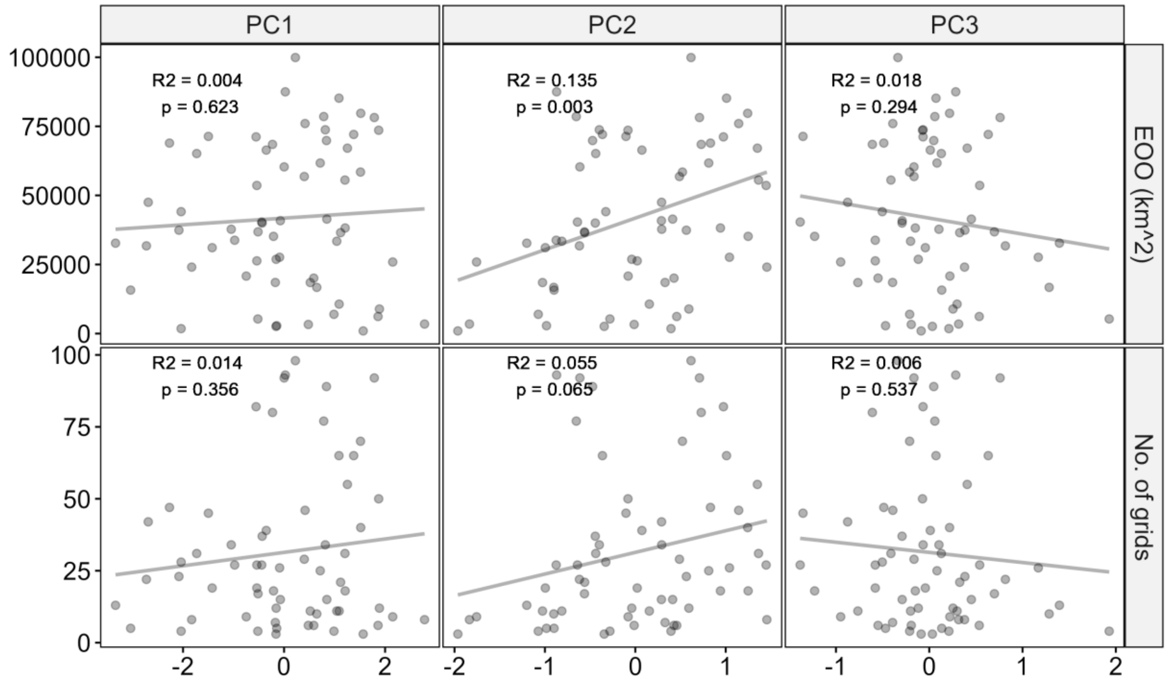
B



X

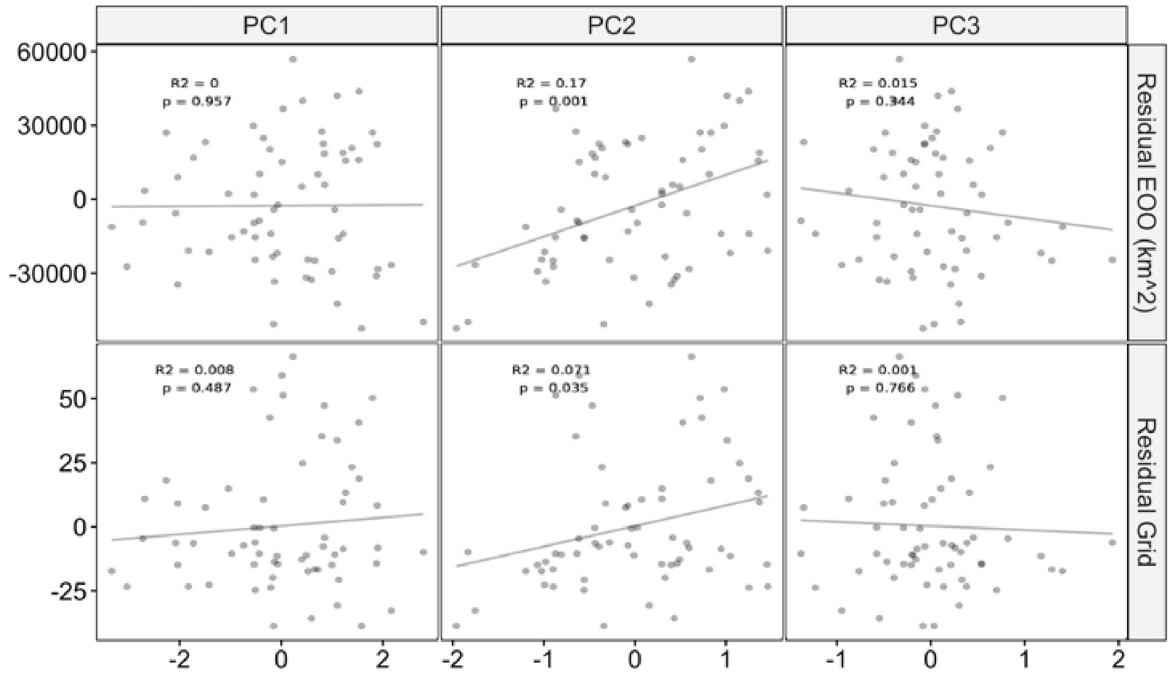
Supplementary Figure 5: Relation between individual traits Maxheight (Hmax), Specific leaf area (SLA) and Seed mass(SM) with other two invasion status proxies- Extent of Occurrence (EOO) and Number of grids. To control for first date of occurrence linear regression is used. Residual values is the difference between observed values and predicted values. A) before controlling for first date of occurrence B) after controlling for first date of occurrence. Before control SLA has significant relation with both EOO and number of grids. Similar relation is seen after control as well.

A



PC1
PC2
PC3
R2 = 0.004
p = 0.623
R2 = 0.135
p = 0.003
R2 = 0.018
p = 0.294
R2 = 0.014
p = 0.356
R2 = 0.055
p = 0.065
R2 = 0.006
p = 0.537
100000
75000
50000
25000
0
100
75
50
25
0
-2
0
2
-2
-1
0
1
-1
0
1
2
EOO (km^2)
No. of grids

B



PC1
PC2
PC3
R2 = 0
p = 0.957
R2 = 0.17
p = 0.001
R2 = 0.015
p = 0.344
R2 = 0.008
p = 0.487
R2 = 0.071
p = 0.035
R2 = 0.001
p = 0.766
60000
30000
0
-30000
50
25
0
-25
-2
0
2
-2
-1
0
1
-1
0
1
2
Residual EOO (km^2)
Residual Grid

Supplementary Figure 6: Relation between combination of traits Maxheight (Hmax), Specific leaf area (SLA) and Seed mass(SM) shown by PC axes with other two invasion status proxies- Extent of Occurrence (EOO) and Number of grids. To control for first date of occurrence linear regression is used. Residual values is the difference between observed values and predicted values. A) before controlling for first date of occurrence B) after controlling for first date of occurrence. Before control SLA has significant relation with both EOO but not with number of grids. After control relation is significant for both the proxies.

Supplementary Table 1- Results of linear regression and significance test of invasion proxies extent of Occurrence (EOO) and number of grids. Residual value is the difference between observed value and predicted value to control for the first date of occurrence. We looked at all combination of traits and proxies. PC axes represent the combination of the three trait MaxHeight (Hmax), Specific leaf area (SLA) and Seed mass (SM). Bold values shows significant relation

	EOO	Residual_EOO	Number of grids	Residual_No of grids
logHmax	R2-0, p-0.883	R2-0.002, p-0.717	R2-0.006, p-0.533	R2-0.001, p-0.848
logSLA	R2-0.095, p-**0.014**	R2-0.93, p-**0.015**	R2-0.062, p-0.048	R2-0.065, p-**0.043**
logSM	R2-0.015; p-0.336	R2-0.032, p-0.158	R2-0, p-0.937	R2-0.001, p-0.828
PC 1	R2-0.004; p-0.623	R2-0, p-0.957	R2-0.014, p-0.356	R2-0.008, p-0.487
PC 2	R2-0.135; p-**0.003**	R2-0.17, p-**0.001**	R2-0.05, p-0.065	R2-0.071, p-**0.035**
PC 3	R2-0.01; p-0.294	R2-0.015, p-0.344	R2-0.006, p-0.537	R2-0.001, p-0.766

Supplementary 2: Species data used containing name, family, growth form , first date of occurrence, primary habitat, specific leaf area (SLA) in cm^2/g, MaxHeight (Hmax) in cm, Seed mass (SM) of 1000 seed in g and Area of Occupancy (AOO) in km^2

Species	Family	Growth form	SLA (cm^2/g)	MaxHeight (cm)	Seedmass (1000 seeds)(g)	AOO (km^2)
Acacia auriculiformis	Fabaceae	tree	122.769	3000.000	19.601	5615.839
Acanthospermum hispidum	Asteraceae	herb	372.261	173.000	7.580	5314.287
Aeschynomene americana	Fabaceae	herb	230.716	220.000	3.834	1245.699
Ageratina adenophora	Asteraceae	herb	207.772	300.000	0.060	1274.842
Ageratum conyzoides	Asteraceae	herb	424.090	142.500	0.117	42750.922
Ageratum houstonianum	Asteraceae	herb	394.625	100.000	0.120	90.885
Alternanthera ficoidea	Amaranthaceae	herb	310.116	130.800	0.400	770.809
Alternanthera paronychioides	Amaranthaceae	herb	202.976	56.250	0.348	104.182
Alternanthera pungens	Amaranthaceae	herb	223	60.000	0.400	3656.263
Alternanthera sessilis	Amaranthaceae	herb	240.9977	100.000	0.486	5415.800
Antigonon leptopus	Polygonaceae	herb	278.7399	2218.650	70.500	239.221
Argemone mexicana	Papaveraceae	herb	197.2198	150.000	1.975	6011.274
Ascelpias curassavica	Apocynaceae	herb	302.0288	167.500	3.000	11225.064
Bidens biternata	Asteraceae	herb	460.4462	100.000	3.106	6051.546

Bidens pilosa	Asteraceae	herb	356.5616	185.000	1.726	8069.309
Boerhavia erecta	Nyctaginaceae	herb	260.666	126.640	1.794	86.917
Cassia occidentalis	Fabaceae	shrub&liana	153.599	800.000	16.820	7057.601
Cassia spectabilis	Fabaceae	tree	96.426	1800.000	24.524	--
Cassia tora	Fabaceae	herb	288.812	200.000	18.537	11968.713
Cassia uniflora	Fabaceae	herb	195.213	132.500	13.114	--
Celosia argentea	Amaranthaceae	herb	183.915	200.000	0.742	14778.012
Chloris barbata	Poaceae	herb	247.800	100.000	0.193	13875.350
Chromolaena odorata	Asteraceae	shrub&liana	339.230	1000.000	1.167	23622.595
Cleome viscosa	Capparaceae	herb	406.083	148.000	1.237	23283.314
Cryptostegia grandiflora	Apocynaceae	shrub&liana	135.198	437.500	8.712	4891.557
Dalbergia melanoxylon	Fabaceae	tree	104.606	1859.750	70.659	489.809
Datura innoxia	Solanaceae	herb	217.595	200.000	14.542	2291.238
Datura metel	Solanaceae	shrub&liana	150.681	200.000	12.174	3331.638
Datura stramonium	Solanaceae	herb	257.621	200.000	8.469	3243.467
Eclipta prostrata	Asteraceae	herb	225.262	98.398	0.438	7392.334
Eucalyptus globulus-	Myrtaceae	tree	92.2105	6505.000	10.967	5407.309
Euphorbia heterophylla	Euphorbiaceae	herb	259.399	200.000	6.020	7444.184
Euphorbia hirta	Euphorbiaceae	herb	278.265	116.000	0.098	33953.431
Euphorbia indica	Euphorbiaceae	herb	245.259	94.500	0.645	15067.689
Galinsoga pariviflora	Asteraceae	herb	411.800	80.000	0.204	563.121

Hyptis suaveolens	Lamiaceae	shrub&liana	231.510	300.000	4.554	4510.065
Indigofera linnaei	Fabaceae	herb	187.313	50.000	1.716	1402.071
Ipomoea carnea	Convolvulaceae	shrub&liana	148.713	600.000	79.200	2965.522
Ipomoea hederifolia	Convolvulaceae	herb	219.632	607.000	12.755	6966.753
Jatropha curcas	Euphorbiaceae	tree	160.096	900.000	626.103	11352.876
Lantana camara	Verbanaceae	shrub&liana	297.924	461.000	15.357	4976.450
Leucaena leucocephala	Fabaceae	tree	200.008	1930.000	45.226	177.775
Ludwigia erecta	Onagraceae	herb	296.474	300.000	0.063	--
Malachra capitata	Malvaceae	shrub&liana	218.155	200.000	4.027	--
Malvastrum coromendalianum	Malvaceae	herb	404.479	107.500	1.396	8749.783
Mercardonia procumbens	Plantaginaceae	herb	221.865	16.800	0.006	263.398
Mikania micrantha	Asteraceae	herb	286.183	1520.000	0.090	--
Mimosa pudica	Fabaceae	shrub&liana	192.122	200.000	5.226	2999.415
Mirabilis jalapa	Nyctaginaceae	herb	338.339	137.500	77.032	7033.971
Mutingia calabura	Muntingiaceae	tree	208.212	1675.000	0.195	158.343
Oxalis corniculata	Oxalidaceae	herb	328.573	46.675	0.193	12381.450
Parthenium hysterophorus	Asteraceae	herb	323.407	200.000	0.557	4153.747
Passiflora foetida	Passifloraceae	shrub&liana	351.941	940.500	8.672	1190.218
Physalis angulata	Solanaceae	herb	470.150	200.000	0.776	34539.175
Portulaca pilosa	Portulacaceae	herb	169.663	28.600	0.056	2390.860

Portulaca quadrfida	Portulacaceae	herb	198.096	9.050	0.118	7921.713
Prosopis juliflora	Fabaceae	tree	190.201	1500.000	48.115	1070.414
Ricinus communis	Euphorbiaceae	shrub&liana	207.111	1130.000	300.741	2921.172
Solanum americanum	Solanaceae	herb	596.852	150.500	0.623	--
Solanum torvum	Solanaceae	shrub&liana	185.746	496.150	1.083	4746.766
Stachytarpheta jamaicensis	Verbanaceae	herb	209.701	225.000	2.305	45.040
Stylosanthes hamata	Fabaceae	herb	169.519	111.100	2.849	3823.254
Synedrella nodiflora	Asteraceae	herb	474.551	132.000	0.655	3705.924
Synedrella vialis	Asteraceae	herb	357.432	29.000	1.397	--
Tithonia diversifolia	Asteraceae	shrub&liana	206.098	465.000	4.981	2201.964
Tribulus terrestris	Zygophyllaceae	herb	176.172	70.000	25.488	15361.400
Tridax procumbens	Asteraceae	herb	372.773	68.500	0.687	8450.706
Triumfetta rhomboidea	Malvaceae	shrub&liana	303.842	172.500	5.695	46256.046
Typha domingensis	Typhaceae	herb	59.970	400.000	0.122	--
Xanthium strumarium	Asteraceae	herb	173.186	200.000	175.054	4566.680
Zinnia peruviana	Asteraceae	herb	304.071	100.00	4.035	6670.320