Impacts of Acacia and native species in afforestation: A comparison study using floral diversity

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Abstract

In this project, we collect and study the floral diversity of the acacia plantations of the area and compare it with the restored forest land taking floral diversity of the native forest of the area as a reference. The objective is to understand the conditions imparted by acacia plantation to its environment and to analyze the effectiveness of its restoration by comparing it with an adjacent native forest. The project carried out by collecting floral diversity data from the selected sites and subjecting it to various parameters for diversity assessment such as diversity indices, Dominance index, Species richness, Species evenness, abundance, percentage frequency, abundance/frequency ratio (A/F). From research it has been scientifically identified that the acacia plantations impart damaging behaviors to the ecosystem and these properties have been improved on restoration with native species. This can be recognized from various calculated factors such as the following; improved taxonomic diversity of restored forests (20, 33, 14 & 14) from the acacia plantation (16, 12, 13 & 10) which is similar to that of native forest. The calculated dominance index of acacia plantation is 0.1951and of restored forest is 0.1092. This indicates the high dominance of acacia species in the plantation sites which has been regulated on restoration. Simpson's index represents the improved diversity of restored sites (0.8908) from plantation (0.8049). Chao-1 represents the improved species richness in the restored sites (72.75) from plantation sites (15.0825). Calculation of species evenness also indicates the reduced evenness in the plantation (1.7639) and its improvement on restoration (2.0296). Abundance & A/F ratio indicates low diversity of the plantation due to degradation. Research shows that on restoration, floral diversity has been successfully improved that it has the potential to turnout into a healthy, self-sustaining forest similar to the natural forest studied.

Key words Biodiversity; vegetation analysis; exotic species; diversity indices; invasive species

Introduction

While opting for afforestation choices it seems convenient to choose exotic species as nursing crops as they are usually of low maintenance, fast growing and also provide some economic benefits. But the ecological and environmental impacts they impose is hugely under studied (Koutika et al, 2019).

The proposed project aimed to understand the impacts of exotic species in this case, "**Acacia**" on environment in the terms of floral diversity by subjecting it to various parameters of diversity and carrying out a comparison study with restored & native forest types. Literature review carried out prior to research provided indications about the high invasive behavior (Heringer et al., 2019), reductions of various nutrients (P and K^+, exchangeable Ca^{2+} and Mg^{2+} and pH) in depths of soil (Derbel et al., 2009; Santana et al., 2015), observed degradation of nearby native forests from rich to poorer condition, limited potential for improving ecosystem function and fostering succession, negative impact to abundance, basal area, and height of native woody species etc. (Jones. et al., 2017; Kumari et al., 2017; Paudyal et al., 2020).

To carry out the research work, floral diversity data of various forest lands (Acacia plantation, restored forest & native forest) in the area of Chembikkunnu of Kerala, India has been collected, studied and subjected to various parameters of floral diversity.

Methods

Study area

The project has been carried out in the region named Chembikunnu of Wadakkanchery forest range of Kerala in the months of January – March 2023. The area holds pulpwood plantations spread across over 500 Ha. It has been previously leashed out by Hindustan News Print Limited (HNL) for cultivation and utilization of common types of pulpwood such as Acacia & Eucalyptus. But later it is found that the water and nutrient depleting characteristics of such plants is greatly degrading the area. Overgrowth of invasive plants and frequent forest fires due to high fuel load also added up to further degradation of the land. Recently in the year 2020 three forest guards lost their lives in the attempt to stop the wildfires. On understanding the damages the plantations impose, The Kerala Forest Department is carrying out an Eco restoration project in the area. As part of this, the department had cleared out the acacia plantations and planted fruit tree seedlings. Saplings of indigenous species, including mango, jackfruit, guava, jamun, gooseberry, *Gmelina arborea*, bamboo, *Terminalia bellirica* and *Wrightia tinctoria* has been planted in 475 Hectors of area (Eco-restoration_Chembikunnu).

Figure 1: Google image of the restoration sites of Chembikunnu, Kerala

Method of vegetation analysis (Quadrat method):

A quadrat is a frame that is laid down to mark out a specific area of the community to be sampled. Within the quadrat frame, the occurrence of plants is recorded using an appropriate measure of abundance (Baxer, J). The procedure of data collection has been carried out as follows;

Plot establishment- For the assessment, floral species diversity data of the acacia plantation, restored forest land and that of native forest land is required to be collected and analyzed. For these four quadrants from each of the forest types has been marked. Plot establishment is carried out using compass and measuring tape, identifying 10*10m sample plots. In each 10*10 quadrats, 5*5 quadrats and 1*1 quadrats have been marked. Each quadrant is 10*10 square meters of size from which floral diversity data of various vegetations has been collected (Chao, A, 1987). For each type of vegetations, the quadrant size is considered as follows.

Table 1: Quadrat size chosen for each vegetation

Vegetation	Dimensions	Area (m2)
Trees	10*10 m	100
Shrub	5*5 m	25
forest floor herb, creeper & climber	1*1 m	1

From each forest type, four such 10*10 quadrats are marked, from each 10*10 m quadrant; tree species, 5*5 m quadrant; shrub species and 1*1 m quadrant; herb, grass, creeper and climber species has been noted.

Sampling procedure- using quadrat method, 10*10m tree layer is marked. Tree species inside the quadrat are noted by counting. Inside the quadrat 5*5m shrub layer plots and 1*1m herb layer plots are marked and floral diversity is noted.

Plant identification methods- plant identification is done by analyzing diagnostic factors such as orientation and texture of stem, branches and bark; leaf size, shape and arrangement; noting fruits and flowers; identifying barbs, hairs or thrones; noting the smell etc. Determination of unidentified species is done by expert determination and referencing herbarium.

Procedure of data analysis- The data collected from acacia plantation, restored and natural forest land is subjected to comparison study on various factors of floral diversity assessment such as diversity indices (Simpson's diversity index, Shannon's diversity index, evenness, Brillouin's index, menhinick's richness, margalef's index, equitability, fishers alpha index, Berger-parker index), dominance index, taxonomic diversity, species evenness, species richness, diversity of families, Abundance, Percentage frequency & The abundance frequency ratio.

Results

Floral diversity record of the different forest types:

Floral diversity of Acacia plantation; the plantation area dominantly consists of acacia species with very small forest floor diversity. The area is highly sensitive to forest fires due to high fuel load and due to the properties of acacia plants. Four quadrants of ten square meters has been marked in the plot and floral diversity is noted as follows.

Figure 2: Photograph of Acacia plantation

Table 2: Floral diversity record of acacia plantation

Acacia plantation quadrat-1						
Sr. No	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Earleaf acacia	*Acacia auriculiformis*	Fabaceae	Tree	13	100
2	Mangium	*Acacia mangium*	Fabaceae	Tree	1	100
3	Vatta	*Macaranga peltate*	Euphorbiaceae	Seedling	5	100
4	Kamala tree	*Mallotus philippensis*	Euphorbiaceae	Seedling	1	100
5	Blackboard tree	*Alstonia scholaris*	Apocynaceae	Seedling	2	100
6	Manjanathi	*Morinda tinctorial*	Rubiaceae	Seedling	1	100
7	Governor's plum	*Flacourtia indica*	Salicaceae	Seedling	4	100
8	Hill glory bower	*Clerodendrum infortunatum*	Lamiaceae	Shrub	14	25
9	Goanese lpecac	*Naregamia alata*	Meliaceae	Herb	38	1
10	Heartleaf sida	*Sida cordata*	Malvaceae	Herb	1	1
11	Chinease bur	*Triumfetta rhomboidea*	Malvaceae	Herb	1	1
12	Running mountain grass	*Oplismenus compositus*	Poaceae	Grass	2	1
13	Woolly foxglove	*Digitalis lanata*	Plantaginaceae	Grass	32	1
14	Paalvally	*Ichnocarpus frutescens*	Apocynaceae	Climber	6	1
15	Yellow kolambi	*Merremia vitifolia*	Convolvulaceae	Climber	1	1
16	Indian sarasaparilla	*Hemidesmus indicus*	Apocynaceae	Creeper	3	1

Acacia plantation quadrat-2						
Sr. No.	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Ear-leaf acacia	*Acacia auriculiformis*	Fabaceae	Tree	17	100
2	Manjanathi	*Morinda tinctorial*	Rubiaceae	Tree	1	100
3	Strychnine tree	*Strychnos nux-vomica*	Loganiaceae	Tree	2	100
4	Nag kuda	*Tabernaemontana alternifolia*	Apocynaceae	Seedling	1	100
5	Black board tree	*Alstonia scholaris*	Apocynaceae	Seedling	1	100
6	Hill glory bower	*Clerodendrum infortunatum*	Laminaceae	Shrub	9	25
7	Siam weed	*Chromolaena odorata*	Asteraceae	Shrub	2	25
8	Lettuce-Leaf Blumea	*Blumea lacera*	Asteraceae	Herb	1	1
9	Goanese lpecac	*Naregamia alata*	Melicaceae	Herb	6	1
10	Running mountain grass	*Oplismenus compositus*	Poaceae	Grass	4	1
11	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	1	1
12	Paalvally	*Ichnocarpus frutescens*	Apocynaceae	Climber	4	1
13	Indian sarasaparilla	*Hemidesmus indicus*	Apocynaceae	Creeper	2	1
Acacia plantation quadrat-3						
Sr. No.	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Manjanathi	*Morinda tinctorial*	Rubiaceae	Tree	5	100
2	Ear-leaf acacia	*Acacia auriculiformis*	Fabaceae	Tree	20	100
3	Giant thorny bamboo	*Bambusa bambos*	Poaceae	Bamboo	1(12 culms)	100
4	Vatta	*Macaranga peltate*	Euphorbiaceae	Seedling	4	100
5	Black board tree	*Alstonia scholaris*	Apocynaceae	Seedling	1	100
6	Hill glory bower	*Clerodendrum infortunatum*	Laminaceae	Shrub	12	25
7	Goanese lpecac	*Naregamia alata*	Melicaceae	Herb	3	1
8	Chinease bur	*Triumfetta rhomboidea*	Malvaceae	Herb	1	1
9	Running mountain grass	*Oplismenus compositus*	Poaceae	Grass	3	1
10	Paalvally	*Ichnocarpus frutescens*	Apocynaceae	Climber	4	1
11	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	8	1
12	Indian sarasaparilla	*Hemidesmus indicus*	Apocynaceae	Creeper	2	1
Acacia plantation quadrat-4						
Sr. No.	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Ear-leaf acacia	*Acacia auriculiformis*	Fabaceae	Tree	22	100
2	Manjanathi	*Morinda tinctorial*	Rubiaceae	Tree	3	100

3	Vatta	*Macaranga peltate*	Euphorbiaceae	Seedling	1	100
4	Hill glory bower	*Clerodendrum infortunatum*	Laminaceae	Shrub	12	25
5	Indrajao	*Holarrhena pubescens*	Apocynaceae	Shrub	1	25
6	Siam weed	*Chromolaena odorata*	Asteraceae	Shrub	2	1
7	Valli jasmine	*Jasminum coarctatum*	Oleaceae	Climbing shrub	3	1
8	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	3	1
9	Paalvally	*Ichnocarpus frutescens*	Apocynaceae	Climber	2	1
10	Thippelli	*Piper longum*	Piperaceae	Climber	3	1

Floral diversity of Restored Forest:

The restored forests are part of the restoration project of Kerala Forest Department. As part of the restoration program, the acacia forests of 475 Hectors have been uprooted and replaced with native plants, mostly fruit species. Four quadrants of ten square meter quadrants have been marked in the selected plots of restored forest and floral diversity has been noted.

Figure 3: Photograph of restored forest land

Table 3: Floral diversity record of the restored forest land

Sr. No.	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
		Restored land quadrat-1				
1	Manjanathi	*Morinda tinctoria*	Rubiaceae	Tree	1	100
2	Indian elm	*Holoptelea integrifolia*	Ulmaceae	Tree	9	100
3	Indian gooseberry	*Phyllanthus emblica*	Phyllanthaceae	Tree	1	100
4	Strychnine tree	*Strychnos nux-vomica*	Loganiaceae	Tree	1	100
5	Chandada	*Macaranga peltata*	Euphorbiaceae	Tree	1	100
6	Indian coral tree	*Erythrina stricta*	Fabaceae	Tree	1	100
7	Spinous kino tree	*Bridelia retusa*	Phyllanthaceae	Tree	1	100
8	Indian screw tree	*Helicteres isora*	Malcaceae	Shrub	1	25
9	Cup saucer plant	*Breynia retusa*	Phyllanthaceae	Shrub	1	25
10	Narrow leaved canthium	*Canthium anguistifolium*	Rubiaceae	Shrub	1	25
11	Mission grass	*Pennisetum polistachion*	Poaceae	Grass	1	1
12	Bush weed	*Flueggea suffruticosa*	Phyllanthaceae	Herb	1	1
13	Cinderella weed	*Synedrella nodiflora*	Asteraceae	Herb	1	1
14	Comb Rungia	*Rungia pectinata*	Acanthaceae	Herb	5	1
15	Siam weed	*Chromolaena odorata*	Asteraceae	Herb	4	1
16	Chinease bur	*Triumfetta rhomboidea*	Malvaceae	Herb	1	1
17	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	5	1
18	Yellow kolambi	*Merremia vitifolia*	Convolvulaceae	Climber	3	1
19	Pullanji	*Calycopteris floribunda*	Combretaceae	Climber	1	1
20	Indian sarasaparilla	*Hemidesmus indicus*	Asclepiadaceae	Creeper	2	1
		Restored land quadrat-2				
1	Nag kuda	*Tabernaemontana alternifolia*	Apocynaceae	Seedling	1	100
2	Vatta	*Macaranga peltata*	Euphorbiaceae	Tree	1	100
3	Indian trumpet tree	*Oroxylum indica*	Bignoniaceae	Seedling	1	100
4	Njaval	*Syzigium cumini*	Myrtaceae	Seedling	1	100
5	Manjanathi	*Morinda tinctoria*	Rubiaceae	Tree	3	100
6	Kamala tree	*Mallotus philipensis*	Euphorbiaceae	Tree seedling	4	100
7	Kusum tree	*Schleichera oleosa*	Sapindaceae	Tree	1	100
8	Indian gooseberry	*Phyllanthus emblica*	Phyllanthaceae	Seedling	3	100
9	Blackboard tree	*Alstonia scholaris*	Apocynaceae	Huge tree	1	100

					No. species	Area (m^2)
10	Pongam tree	*Pongamia pinnata*	Fabaceae	Tree seedling	1	100
11	Pigeon wood	*Trema orientalis*	Cannabaceae	Tree seedling	1	100
12	Cup saucer plant	*Bridelia retusa*	Phyllanthaceae	Shrub	1	25
13	Black-honey shrub	*Phyllanthus reticulatus*	Phyllanthaceae	Shrub	1	25
14	Common lantana	*Lantana camera*	Verbenaceae	Shrub	1	25
15	Kaara	*Canthium angustifolium*	Rubiaceae	Shrub	1	25
16	Hill glory bower	*Clerodendron infortunatum*	Lamiaceae	Shrub seedling	1	25
17	Heartleaf sida	*Sida cordata*	Malvaceae	Herb	1	1
18	Tropical gridlepod	*Mitracarpus hirtus*	Rubiaceae	Herb	1	1
19	Chinease bur	*Triumfetta rhomboidea*	Malvaceae	Herb	1	1
20	Himalayan ruellia	*Phaulopsis imbricata*	Acanthaceae	Herb	1	1
21	Sarpagandhi	*Rauvolfia serpentina*	Apocynaceae	Herb	1	1
22	Siam weed	*Chromolaena odorata*	Asteraceae	Herb	8	1
23	Common wireweed	*Sida acuta*	Malvaceae	Herb	1	1
24	Comb rungia	*Rungia pectinata*	Acanthaceae	Herb	2	1
25	Sensitive plant	*Mimosa pudica*	Fabaceae	Herb	1	1
26	Goanese lpecac	*Naregamia alata*	Meliaceae	Herb	1	1
27	Mission grass	*Pennisetum polystachium*	Poaceae	Grass	3	1
28	Maiden hair creeper	*Lygodium flexuosum*	Schizaeaceae	Climber	1	1
29	Indian moon seed	*Cyclea peltata*	Menispermaceae	Climber	1	1
30	Manja kolambi valli	*Merremia vitifolia*	Convolvuaceae	Climber	3	1
31	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	1	1
32	Pullanji	*Calycopteris floribunda*	Combretaceae	Climber	5	1
33	Indian sarasaparilla	*Hemidesmus indicus*	Apocynaceae	Creeper	1	1

Restored land quadrat-3						
Sr. No.	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Indian Nettle tree	*Trema orientalis*	Cannabaceae	Tree	15	100
2	Njaval	*Syzygium cumini*	Myrtaaceae	Seedling	3	100
3	Indian elm	*Holoptelea integrifolia*	Ulmaceae	Seedling	1	100
4	Earleaf acacia	*Acacia auriculiformis*	Fabaceae	Seedling	1	100
5	Kamala tree	*Mallotus philippensis*	Euphorbiaceae	Tree	1	100
6	Manjanathi	*Morinda tinctoria*	Rubiaceae	Tree	1	100
7	Sensitive plant	*Mimosa pudica*	Fabaceae	Herb	2	1
8	Heartleaf sida	*Sida cordata*	Malvaceae	Herb	5	1
9	Siam weed	*Chromolaena odorata*	Asteraceae	Herb	2	1

					No. species	Area (m^2)
10	Mission grass	*Pennisetum polystachium*	Poaceae	Grass	8	1
11	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	1	1
12	Indian sarasaparilla	*Hemidesmis indicus*	Apocynaceae	Creeper	3	1
13	Paalvally	*Ichnocarpus frutescens*	Apocynaceae	Climber	4	1
Restored land quadrat-4						
Sr. No.	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	White teak	*Gmelina arborea*	Lamiaceae	Tree	7	100
2	Nag kuda	*Tabernaemontana alternifolia*	Apocynaceae	Tree seedling	1	100
3	Noni	*Morinda tinctoria*	Rubiaceae	Tree seedling	1	100
4	Kamala tree	*Mallotus philippensis*	Euphorbiaceae	Seedling	1	100
5	Pullanji	*Calycopteris floribunda*	Combretaceae	Seedling	3	100
6	Earleaf acacia	*Acacia auriculiformis*	Fabaceae	Seedling	1	100
7	Indian elm	*Holoptelia integrifolia*	Ulmaceae	Seedling	1	25
8	Siam weed	*Chromaleana odorata*	Asteraceae	Herb	6	1
9	Kongini	*Lantana camara*	Verbenaceae	Herb	1	1
10	Creeping sebastiana	*Sebastiania chamaelea*	Euphorbiaceae	Herb	1	1
11	Mission grass	*Pennisetum polystachium*	Poaceae	Grass	1	1
12	Naikurani	*Mucuna pruriens*	Fabaceae	Climber	2	1
13	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	1	1
14	Paalvally	*Ichnocarpus frutescens*	Apocynaceae	Climber	2	1
15	Stinking passionflower	*Passiflora foetida*	Passifloraceae	Climber	1	1

Floral diversity of Native Forest: The native forest considered for study is located adjacent to the Eco restored plots sharing the same topography and climate. Reference on the floral diversity of the natural forest gives indications about the climax forest possible for the eco restored sites. The native was a dry deciduous forest highly covered by lianas and climber species.

Figure 4: Photograph of native forest studied

Table 4: Floral diversity record of native forest studied

natural forest quadrat-1						
Sr. No	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Ear leaf acacia	*Acacia auriculiformis*	Fabaceae	Tree	1	100
2	Cashew	*Anacardium occidentale*	Anacardiaceae	Tree	1	100
3	Indian Laurel	*Terminalia elliptica*	Combretaceae	Tree	4	100
4	Hoom	*Miliusa tomentosa*	Annonaceae	Tree	1	100
5	Orangeberry	*Glycosmis pentaphylla*	Rutaceae	Shrub	12	25
6	Hill glory bower	*Clerodendrum infortunatum*	Lamiaceae	Shrub	11	25
7	Cup saucer plant	*Breynia retusa*	Phyllanthaceae	Shrub	6	25
8	Red Bead Tree	*Adenanthera pavonina*	Fabaceae	Seedling	1	25
9	kamala tree	*Mallotus philipensis*	Euphorbiaceae	Seedling	5	25
10	Vatta	*Macranga peltate*	Euphorbiaceae	Seedling	5	25
11	Nag kuda	*Tabernaemontana alternifolia*	Apocynaceae	Seedling	1	25
12	Toothed-Leaf Limonia	*Naringi crenulate*	Rutaceae	Seedling	1	25
13	Rose Sandal Wood	*Olea dioica*	Oleaceae	Seedling	2	25
14	Palmyra palm	*Borassus flabellifer*	Arecaceae	Seedling	4	25

15	Tamarind	*Tamarindus indica*	Caesalpiniaceae	Seedling	1	25
16	Goanese lpecac	*Naregamia alata*	Meliaceae	Herb	24	1
17	Black creeper	*Ichnocarpus frutenscens*	Apocynaceae	Herb	3	1
18	Winged stalk desmodium	*Desmodium triquetrum*	Fabaceae	Herb	1	1
19	Running mountain grass	*Oplismenus compositus*	Poaceae	Grass	10	1
20	Tropical kudzu	*Pueraria phaseoloides*	Fabaceae	Climber	1	1
21	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	1	1
22	Indian sarasaparilla	*Hemidesmus indicus*	Apocynaceae	Climber	2	1

Natural forest quadrat-2						
Sr. No	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Black Siris	*Albizia odoratissima*	Fabaceae	Tree	1	100
2	Golden shower tree	*Cassia fistula*	Fabaceae	Tree	1	100
3	Indian Laurel	*Terminalia elliptica*	Combretaceae	Tree	1	100
4	kusum tree	*Schleichera oleosa*	Sapindaceae	Tree	1	100
5	Toothbrush tree	*Streblus asper*	Moraceae	Seedling	5	100
6	Manjanathi	*Morinda tinctorial*	Rubiaceae	Seedling	1	100
7	Kamala tree	*Mallotus philipensis*	Euphorbiaceae	Seedling	7	100
8	Rose Sandal Wood	*Olea dioica*	Oleaceae	Seedling	2	100
9	Orangeberry	*Glycosmis pentaphylla*	Rutaceae	Shrub	1	25
10	Narrow-leaved canthium	*Canthium angustifolium*	Rubiaceae	Shrub	8	25
11	Cup saucer plant	*Breynia retusa*	Phyllanthaceae	Shrub	1	25
12	Paper Flower Climber	*Calycopteris floribunda*	Combretaceae	Shrub	1	25
13	Governor's plum	*Flacourtia indica*	Salicaceae	Shrub	2	25
14	Squirrel's tail	*Justicia betonica*	Acanthaceae	Herb	4	1
15	Wild jasmin	*Jasminum coarctatum*	Oleaceae	Climbing shrub	1	1
16	Black creeper	*Ichnocarpus frutenscens*	Apocynaceae	Herb	2	1
17	Konkan Eranthemum	*Eranthemum capens*	Acanthaceae	Herb	3	1
18	Himalayan ruellia	*Phaulopsis imbricate*	Acanthaceae	Herb	1	1

Natural forest quadrat-3						
Sr. No	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Chadachi	*Grewia tiliifolia*	Malvaceae	Tree	1	100
2	Manjanathi	*Morinda tinctorial*	Rubiaceae	Tree	3	100
3	Palm tree	*Caryota urens*	Arecaceae	Tree	1	100
4	Tree of heaven	*Ailanthus excels*	Simaroubaceae	Tree	1	100
5	Teak	*Tectona grandis*	Lamiaceae	Tree	1	100

Sr. No	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
6	Golden shower tree	*Cassia fistula*	Fabaceae	Tree	2	100
7	Vatta	*Macranga peltate*	Euphorbiaceae	Seedling	2	100
8	Opposite leaf Fig	*Ficus hispida*	Moraceae	Seedling	6	100
9	Rose Sandal Wood	*Olea dioica*	Oleaceae	Seedling	2	100
10	Orangeberry	*Glycosmis pentaphylla*	Rutaceae	Shrub	18	25
11	Narrow-leaved canthium	*Canthium angustifolium*	Rubiaceae	Shrub	2	25
12	Paper Flower Climber	*Calycopteris floribunda*	Combretaceae	Shrub	6	25
13	Wild jasmin	*Jasminum coarctatum*	Oleaceae	Climbing shrub	5	1
14	Indian sarasaparilla	*Hemidesmus indicus*	Apocynaceae	Climber	2	1
15	Black creeper	*Ichnocarpus frutenscens*	Apocynaceae	Herb	3	1
16	Running mountain grass	*Oplismenus compositus*	Poaceae	Grass	6	1

Natural forest quadrat-4

Sr. No	Common name	Scientific name	Family	Habit	No. species	Area (m^2)
1	Palm tree	*Caryota urens*	Arecaceae	Tree	1	100
2	Golden shower tree	*Cassia fistula*	Fabaceae	Tree	1	100
3	Kamala tree	*Mallotus philipensis*	Euphorbiaceae	Tree	1	100
4	Vatta	*Macranga peltate*	Euphorbiaceae	Tree	2	100
5	Strychnine tree	*Strychnos nux-vomica*	Loganiaceae	Tree	1	100
6	Nag kuda	*Tabernaemontana alternifolia*	Apocynaceae	Seedling	4	100
7	Rose Sandal Wood	*Olea dioica*	Oleaceae	Seedling	1	100
8	Torch tree	*Ixora pavetta*	Rubiaceae	Seedling	1	100
9	Opposite leaf Fig	*Ficus hispida*	Moraceae	Seedling	3	100
10	Kamala tree	*Mallotus philipensis*	Euphorbiaceae	Seedling	2	100
11	Hill glory bower	*Clerodendrum infortunatum*	Laminaceae	Shrub	5	25
12	Narrow-leaved canthium	*Canthium angustifolium*	Rubiaceae	Shrub	15	25
13	Black creeper	*Ichnocarpus frutenscens*	Apocynaceae	Herb	2	1
14	Goanese lpecac	*Naregamia alata*	Melicaceae	Herb	1	1
15	Wild jasmin	*Jasminum coarctatum*	Oleaceae	Climbing shrub	1	1
16	Indian sarasaparilla	*Hemidesmus indicus*	Apocynaceae	Climber	1	1
17	Black pepper	*Piper nigrum*	Piperaceae	Climber	1	1
18	Tropical kudzu	*Pueraria phaseoloides*	Fabaceae	Climber	1	1
19	Butterfly pea	*Centrosema pubescens*	Fabaceae	Climber	1	1

Taxonomic diversity:

Table 5: Taxonomic diversity of different forest types

Taxonomic diversity	Plantation	Restored	Native
Quadrant-1	16	20	22
quadrant-2	13	33	18
quadrant-3	12	14	16
quadrant-4	10	14	15

The number of different species present in the three forest types namely plantation, restored and native forest indicates current floral diversity conditions of the forests. The four quadrants of acacia plantation has taxonomic diversity (taxa-s) of 16, 12, 13 & 10 while the quadrants in the restored part of the forest shows increased taxonomic diversity of 20, 33, 14 & 14. This is quite similar to taxonomic diversity of healthy natural forest.
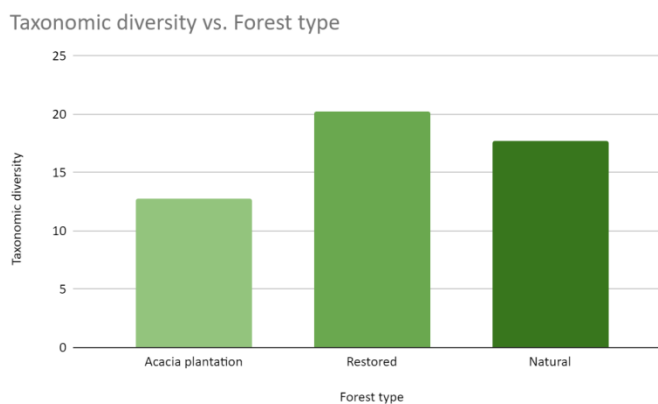
Figure 5: Taxonomic diversity of different forest types

Dominance:

The dominance index calculated shows distinctive differences in the properties of the plantation and restored forest.

Table 6: Dominance index of different forest types

Dominance	Plantation	Restored	Natural
	0.1951	0.1092125	0.1172775

The dominance index of the acacia plantation as an average from the four quadrats is calculated to be 0.1951 (with a std deviation of 0.037 and std error of 0.18). Whereas the dominance values of restored quadrants are shown to be 0.1092125 (with std deviation 0.043 and std error 0.021). This indicates the high dominance of acacia species in the plantation which has been regulated in the restored forest. Dominance of a plant species is unhealthy to an ecosystem. Here the acacia plantation was indented to be a source of raw material for the pulp & paper industry. Later it has been found out that the dominance of acacia species is heavily destructing the forest ecosystem. The species depletes the water and nutrients of the soil and interrupts the water and nutrient cycle which eventually results in frequent forest fires which further depletes the ecosystem.
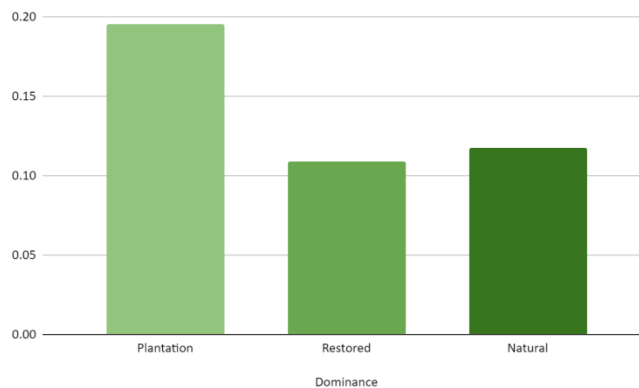
Figure 6: Dominance index in different forest types

Diversity indices:

Various diversity indices namely Simpson's diversity index, Shannon's diversity index, Brillouin's index, menhinicks index, margalefs index, fisher alpha, Berger parker index has been calculated which effectively represents the variations in diversity characteristics of the plantation and restored forest.

Table 7: Diversity indices for different forest types

Diversity indices	Acacia plantation	Restored	Natural
Simpson_1-D	0.8049	0.8908	0.882725
Shannon_H	1.989	2.6025	2.479

Brillouin	1.748	2.11375	2.087
Menhinick	1.5345	3.024	2.4165
Margalef	2.7705	5.0585	4.1965
Fisher_alpha	4.63675	16.4695	9.42175
Berger-Parker	0.343225	0.226175	0.229025

Various diversity indices for the floral diversity assessment have been calculated. The greater the value of Simpson's index, the greater the diversity. From the tabulation it can be seen that the low value of index for acacia plantation has been improved on restoration which is close to that of natural forest. Shannon's diversity index provides an indication of the species richness of an ecosystem. From the tabulation it can be seen that the acacia plantations have the lowest index range (1.989) implifying the low species richness of the land type. Compared to the plantations, restored forest shows improved index values (2.6025). The fisher alpha index shows a significant difference in values between acacia plantations and restored forests. The fisher alpha index measures the evenness with which individuals are divided among the taxa present. The varied evenness present between the plantations and restored forests indicates the relative low abundance of the other species of flora in the acacia field which has been greatly improved through the process of restoration. The other diversity indices calculated also represent the reduced and imbalanced floral diversity of the acacia plantations.
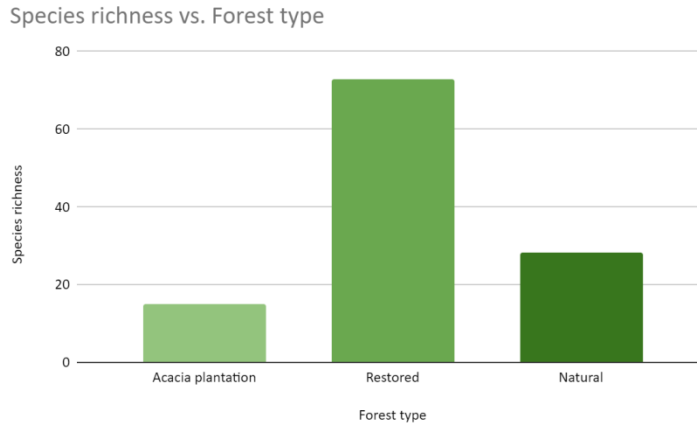
Species richness:

Table 8: Species richness of different forest types

Forest type	Species richness
Acacia plantation	15.0825
Restored	72.75
Natural	28.23

The species richness indicated by the index Chao-1 represents the varied species evenness difference between acacia plantation and restored forests. The species richness as calculated for four quadrats of acacia plantation is obtained as 15.0825 (with std deviation 4.48 and std deviation 2.24). Species richness of restored forest is 72.75 (with std deviation 76.5 and std error

38.25) and that of natural forest is28.23 (with std deviation 7.95 and std error 3.97) This represents the low floral diversity of acacia plantation and its enhancement on restoration.

Figure 7: Species richness of various forest types

Species evenness:

Table 9: Species evenness of different forest types

Forest type	Species evenness
Acacia plantation	1.763914427
Restored	2.029618488
Natural	1.993583734

The species evenness is calculated using the equation, $C = H'/ Log\ S$ which expresses the distribution of abundance across species in a community. The species evenness for acacia plantation as calculated in four quadrats has been averaged which gives the value of 1.7639. Species richness of restored forest is 2.0296 and that of natural forest is 1.99358. Small value of species evenness indicates the less distributed abundance in an ecosystem whereas high values indicate high abundance.
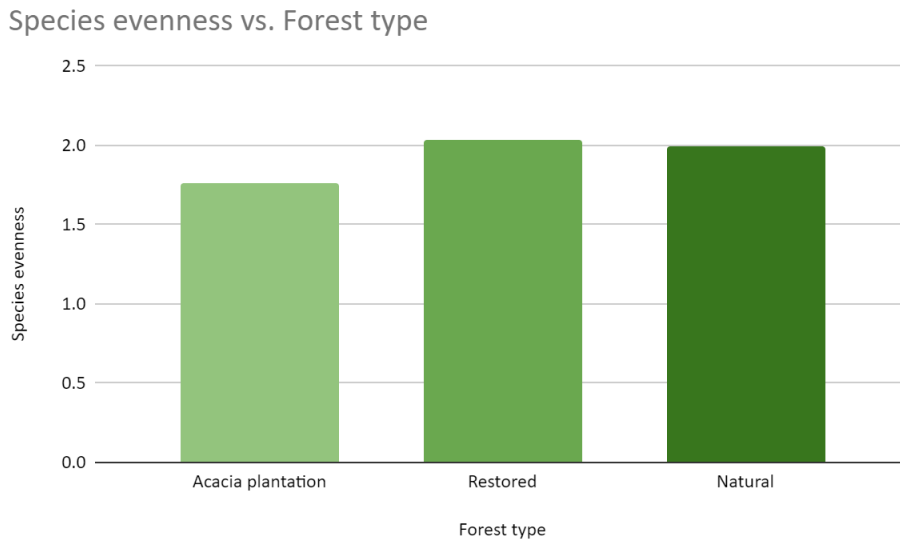
Species evenness vs. Forest type

Figure 8: Species evenness in different forest types

Diversity in families of flora present:

Table 10: Number of families of flora present in different forest types

	Acacia plantation				Restored forest				Natural forest			
No. families	quadrant 1	quadrant 2	quadrant-3	quadrant-4	quadrant-1	quadrant-2	quadrant-3	quadrant-4	quadrant-1	quadrant-2	quadrant-3	quadrant-4
	10	9	8	9	14	22	11	12	14	13	13	14

The comparison between the number of families of plant species present in the plantation and restored forest lands has been carried out. The number of families of flora present in the four quadrants of the plantation are 10, 9, 8 & 9 respectively. This has been improved in the restored forest with the range 14, 22, 11 & 12. of indicates the increased diversity range due to restoration.
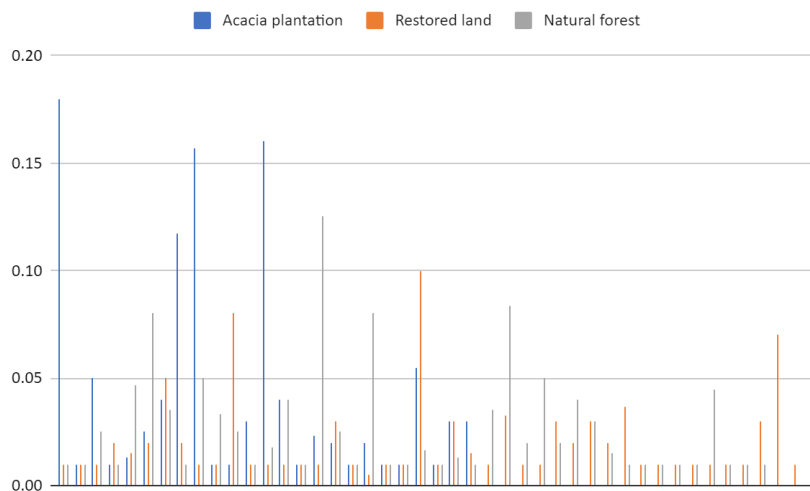
Abundance, frequency and abundance frequency index:

The abundance, percentage frequency and abundance frequency index (A/F) of individual species of four quadrants of the plantation, restored and natural forest has been calculated.

In the plantation the value of abundance index varies widely, that is between the range of 0.25-18 with acacia auriculoformis showing highest abundance. Compared to the acacia species, the rest of the species shows a very low abundance index. This reparents the range of reduced diversity

and evenness of the forest due to degradation. Whereas in the restored forest it is in the range of 0.25-3.25 and in natural forest, in the range of 0.25-6.25.

The abundance frequency ratio of individual species of acacia plantation, restored and natural forest has been calculated which gives an idea of the pattern of species distribution. This ratio indicates distribution pattern of a species as, Regular - (<0.025), Random - (0.025-0.05) and Contagious - (>0.05).

Figure 9: Abundance frequency ratio of Acacia plantation, restored Land and native forest

From the plot showing abundance frequency ratio of acacia plantation, restored and natural forests, the acacia plantation shows relatively highest values indicating the presence of species with regular occurrence (which is acacia).

Discussion

The calculated Dominance index for acacia plantation, restored and natural forests quantify that the dominance index value of acacia plantation is 0.1951. Whereas the dominance value of restored forest is shown to be 0.1092. This indicates the high dominance of acacia species, which affects the balance of the ecosystem. But it has been quantified that as a result of restoration the dominance index has been reduced to smaller values similar to that of natural forest, indicating increased diversity.

Species richness in terms of Chao-1 has been calculated for each of the forest type which is the acacia plantation, restored and native forests. From the calculation it has been clarified that the

acacia plantations have low species richness which has been highly improved on restoration, showing index values similar to that of native forest.

The reduced diversity in number of families of flora present in the acacia plantation has been improved on restoration. The abundance, percentage frequency and abundance frequency ratio of the individual species has been calculated providing indications about the pattern of distribution of individual species.

The project had an objective of Assessment of effectiveness of restoration by conducting a comparison study on floral diversity of acacia plantation and its restored part of land and thereby also evaluating the impact of plantations, taking floral diversity of a healthy natural forest as reference. And on carrying out the assessment with the help of various indices of floral diversity assessment, it has been identified that the acacia plantations has the potential to degrade an ecosystem and with reference of floral diversity assessment of natural forest in the area, it can be said that the Eco restoration project carrying out by the Kerala Forest Department in the plantation area is effectively functional and the restored forests has the potential to eventually turnout into healthy and self-sustaining forests.

From the project carried out it can be further confirmed that, exotic species such as Aacia indeed impact negatively to its surrounding environment & ecology and choosing native crops rather than exotic species is a better choice for afforestation. The research supports that although exotic tree species such as Acacia, Eucalyptus etc., are considered as effective nursing crops for afforestation due to their law maintenance, fast growth and nitrogen fixing abilities, it has the potential to damage the ecosystem over the time due water and nutrient depleting behavior and high invasiveness. From the observations made from research it has been found that restoration carried out using native indigenous species yield more effectiveness than the acacia plantations. Using native species which have market significance such as fruit trees, can also provide a passive benefit other than restoration as done by the Eco restoration project of Chembikunnu.

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Conflict of interest

The author declares no competing interests.

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